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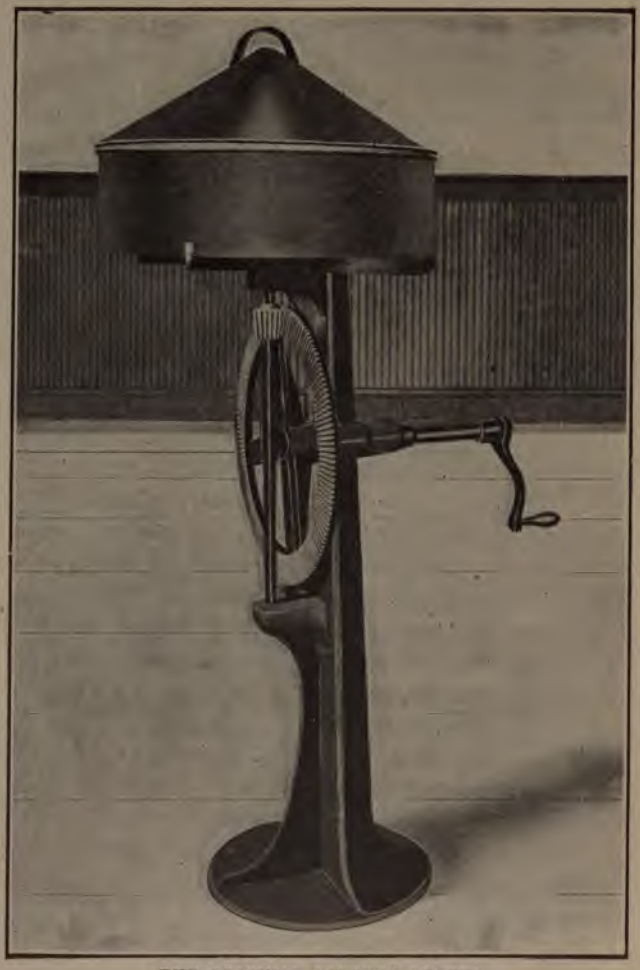

THE ORIGINAL BABCOCK TESTER

Modern Methods of Testing Milk and Milk Products

A HANDBOOK PREPARED FOR THE USE OF DAIRY STUDENTS, BUTTER-MAKERS, CHEESE-MAKERS, PRODUCERS OF MILK, OPERATORS IN CONDENSERIES, MANAGERS OF MILK-SHIPPING STATIONS, MILK-INSPECTORS, PHYSICIANS, ETC.

By

LUCIUS L. VAN SLYKE

Chemist of the New York Agricultural Experiment Station

ILLUSTRATED

SECOND REVISED EDITION

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PREFACE

To attain the highest degree of success in the production of milk and in the manufacture of its products, it has become essential to acquire some knowledge of the methods of testing milk and milk products. The application of these methods to dairying has resulted in lifting the dairy industry to a higher plane of intelligence, and in effecting changes of great economic importance, among which may be briefly mentioned: (1) Greater justice rendered milk producers in paying for milk according to its quality. (2) Prevention of large losses, once very common, in the manufacture of butter and cheese. (3) Improvement of methods of manufacture through better control of details. (4) Increase of yield of products made from a given amount of milk. (5) Improvement in the uniformity and quality of manufactured dairy products.

This little book has been prepared for the use of dairy students, cheese-makers, butter-makers, producers of milk, operators in condenseries, managers of shipping-stations, milk-inspectors, and others interested. Physicians who are specialists in infant-feeding will find the book useful in testing human milk as well as cows' milk that is modified or to be modified.

No previous chemical training is required for operating successfully the methods described. Any intelligent person who can labor with painstaking patience and appreciate the value of attention to little details should be able to master these methods with a rea-

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sonable amount of work. The assistance of a trained teacher will, of course, make the task easier. No one, whatever his educational preparation, can hope to use these or any similar methods successfully who can not or will not follow instructions accurately and exercise patience in mastering every minute detail.

In the preparation of this work, the writer has tried to keep in mind the following points: (1) Accuracy, simplicity and clearness of statement. (2) Making prominent, as far as practicable, the reasons for each step in each process. (3) Emphasis of common difficulties and instructions for overcoming them. (4) Impressing students with the necessity of precision and care in performing every detail given. (5) Selection of the methods approved by experience. (6) Avoidance of such technical methods as require unusual skill or equipment. (7) Omission of unnecessary details. (8) Embodiment of the results of the most recent investigations. (9) The special needs of those for whose use the work is designed.

The scope of this work is far from exhaustive, but the methods selected are given with necessary completeness. Chemical methods, requiring elaborate equipment and extended special training, are purposely omitted. Any one desiring a full description of such methods can obtain it by addressing a request to the U. S. Department of Agriculture, Bureau of Chemistry, Washington, D. C., asking for a copy of "Methods of Analysis adopted by the Association of Official Agricultural Chemists."

The methods that have been compiled here are in large measure the direct result of the work of our

agricultural experiment stations, and afford some indication of the direction and value of the work done by these institutions.

In the preparation of Chapter XVII, valuable assistance has been kindly rendered by Mr. George A. Smith, Dairy Expert of this station.

L. L. VAN SLYKE.

New York Agricultural Experiment Station, 1906.

PREFACE
TO SECOND REVISED EDITION

Five years have passed since this book was last revised. During these few years, new demands have arisen, and, in response, new methods of testing milk and milk products have been developed, which are in constant requirement and which should, therefore, be readily available. Some idea of the extent and direction of the activity in these lines can be gathered from the number and character of the changes introduced in the present edition. Without going into details, it is sufficient to say that four chapters, consisting almost entirely of new matter, have been added, and several other chapters have been completely rewritten and enlarged by incorporation of much additional material, while in only a few chapters has there been no appreciable change. It has been desired to make the revision sufficiently thorough to bring the subject matter fully up to date.

L. L. VAN SLYKE.

Geneva, N. Y., August, 1912.

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Modern Methods of Testing Milk and Milk Products

CHAPTER I

Chemistry of Cow's Milk and Milk Products

THE normal milk of cows contains the following compounds and classes of compounds:

(1) Water.
(2) Fat.
(3) Nitrogen compounds or proteins.
(4) Milk-sugar.
(5) Salts or ash.
(6) Gases.

WATER

The water present in milk, however much its presence may be disguised, is the compound of hydrogen and oxygen with which we are everywhere familiar. The water in milk serves the purpose of holding in solution the soluble constituents of the milk, and it also acts as a diluent, better fitting the mixture for animal nutrition.

Variation.—The amount of water normally contained in milk varies, depending upon such conditions as individuality, breed, stage of lactation, age, character of food, amount of water drunk, state of health, etc. In the case of single milkings of individual cows, the water may vary from 82 to 90 per cent. or more. In the case of milk from herds of cows, the water varies less, usually ranging from 86 to 88 per cent.

The influence of breed.—The following figures, from the records of the N. Y. Agricultural Experiment Station at Geneva, illustrate the influence of breed upon the water content of milk:

NAME OF BREED	*Per cent. of water in milk*
Holstein Friesian	88.20
American Holderness	87.35
Ayrshire	87.25
Short Horn	85.70
Devon	85.50
Guernsey	85.10
Jersey	84.60

The influence of lactation.—The variation of water in milk, as affected by advance of the lactation period, is illustrated by the following figures, which cover a period of ten months from the time of calving:

MONTH OF LACTATION	*Per cent. of water in milk*
1	86.00
2	86.50
3	86.53
4	86.36
5	86.25
6	86.00
7	85.82
8	85.67
9	85.54
10	85.17

There is noticeable a general tendency for the amount of water in milk to increase for the first three months of lactation, after which there is a continuous decrease to the end of the lactation period.

Total solids.—Under the general term of *total solids* or *milk-solids,* we indicate the constituents of the milk other than water (and gases). The per cent. of water in milk subtracted from 100 gives the percentage of milk-solids, which include fat, proteins, milk-sugar and salts or ash. The amount of solids in milk varies with the same conditions that affect the percentage of water in milk, but, of course, in just the reverse manner. Most states prescribe a legal standard for milk-solids, usually 12 per cent., and milk containing less than the legal amount is regarded as adulterated.

MILK-FAT

The composition of milk-fat.—Milk-fat, also called *butter-fat,* is not a single chemical compound, but is a somewhat variable mixture of several different compounds called glycerides. Each glyceride is formed by the chemical union of glycerin as a base with some acid or acids of a particular kind. These glycerin-acid compounds, or glycerides, of milk-fat contain about ten different acids, some being present in small proportions. The four following acids enter most largely into the composition of milk-fat, in the form of their combinations with glycerin: Palmitic acid, oleic acid, myristic acid and butyric acid. The compounds, or glycerides, formed by the combination of glycerin and the acids, have special names derived from the acids; thus, we have palmitin (glycerin combined with palmitic acid), butyrin (glycerin combined with butyric acid), olein, etc. Milk-fat contains, on an average, about 40 per cent. of palmitin, 34 per cent. of olein, 10 per cent. of myristin, 6 per cent. of butyrin, and

from less than 1 to nearly 3 per cent. of each of the glycerides of other acids. Milk-fat contains about 12.5 per cent. of glycerin in combination with the acids. The proportions of these constituents of milk-fat vary somewhat, and this variation influences the character of the milk-fat. Thus, palmitin and myristin tend to make milk-fat harder, while olein and butyrin have the opposite tendency.

The acids contained in milk-fat or butter-fat may be divided into two groups: (1) The acids in one group (palmitic, oleic, myristic, stearic, lauric) are insoluble in water and non-volatile, while (2) the other acids (butyric, caproic, etc.,) are more or less completely soluble in water and are volatile. These differences afford a practical basis for distinguishing pure butter from artificial butter. Of the fat-acids contained in butter-fat, about 87.5 per cent. consists of the insoluble fat-acids, while in other forms of animal fat (beef-fat, lard, etc.,) the amount of these insoluble fat-acids is considerably greater. The amount of volatile fat-acids in milk-fat or butter-fat is much greater than in other forms of animal fat.

Fat-globules in milk.—Milk-fat is present in milk, not in solution, but suspended in the form of very small, transparent globules. Globules varying in size between one twenty-five hundredth and one fifteen-thousandth of an inch in diameter are the ones most commonly present. The average size of fat-globules in milk is somewhat more than one ten-thousandth of an inch in diameter. The smaller globules are more numerous than the larger ones. In one drop of average milk there are more than one hundred million fat-

globules. Skim-milk contains fewer and smaller globules than whole milk, while the reverse is true of cream. The large globules do not differ in composition from the small ones. The size and number of fat-globules in milk are influenced by such conditions as advance of lactation, breed of cow, food, age, health, different milkings, different parts of the same milking, etc.

It was formerly believed generally, and is still by some, that the fat-globules of milk are surrounded by a membranous covering, or else by a semi-liquid, albuminous layer. We may, however, accept it as established beyond reasonable doubt that the fat-globules of milk have no special covering of any kind, but are simply minute particles of fat floating free in milk in the form of an emulsion. Fat-globules quite generally retain their individuality even in butter and cheese.

Amount of fat in milk.—Normal milk varies greatly in its fat content, containing from below 2 to over 10 per cent., if we consider single milkings of individual cows. The milk from herds of cows varies in fat more commonly between the limits of 3 and 5 per cent. The average amount of milk-fat in milk produced in this country, taking the true average for the entire year, lies somewhere near 4 per cent., perhaps a little under. Many of the conditions that affect the percentage of fat in milk are fairly well known, while others are little understood. We will briefly consider some of the well-recognized conditions that influence the fat content of milk.

(1) *Influence of individuality of cow on fat content of milk.*—It is uncommon to find in a herd of

cows two individuals whose milk contains the same per cent. of fat, whether we consider single milkings or the average of many milkings.

(2) *Influence of breed of cow on fat content of milk.*—It is well known that the per cent. of fat in milk varies in a somewhat characteristic way with the kind of breed of cow. While there is marked variation in individuals of the same breed, there is found to be a fairly uniform difference, more or less marked, if we consider the averages of several individuals. It is largely owing to this influence that we find the milk of one country differing from that of another, or the milk of one section of a country differing from that of another section. For example, the average amount of fat in milk in Germany and Holland is fully one-half per cent. lower than in this country, because the prevailing breeds of cows there are those producing milk comparatively low in fat. The following figures, taken from the records of the New York (Geneva) Agricultural Experiment Station, represent averages of many individuals for several periods of lactation:

NAME OF BREED	*Per cent. of fat in milk*		
	Average	Lowest	Highest
Holstein Friesian	3.36	2.88	3.85
Ayrshire	3.60	3.20	4.24
American Holderness	3.73	3.49	3.92
Short Horn	4.44	4.28	4.56
Devon	4.60	4.30	5.23
Guernsey	5.30	4.51	6.13
Jersey	5.60	4.96	6.09

(3) *Influence of age of cow on fat content of milk.*—So far as published data throw light upon this

point, there appears to be a tendency for milk to become less rich in fat with each succeeding period of lactation, especially after the second, though individual exceptions are not infrequent. More data are needed to settle the question definitely.

(4) *Influence of advance of lactation on the fat content of milk.*—In general, it is found that the per cent. of fat in milk increases as the stage of lactation advances after the third month, as illustrated by the following data from the records of the New York (Geneva) Station, covering 10 months from the time of calving:

NUMBER OF MONTH OF LACTATION	*Per cent. of fat in milk*
1	4.54
2	4.33
3	4.28
4	4.39
5	4.38
6	4.53
7	4.56
8	4.66
9	4.79
10	5.00

(5) *Variation of time between milkings in relation to the fat content of milk.*—As a rule, the longer the time between two successive milkings, the smaller is the per cent. of fat in the milk; and the shorter the time between milkings, the greater the per cent. of fat. When the time between milkings is uniformly equal, the variation of fat in milk is small, provided the general environment of the animal is the same. However, as there are not commonly such entirely uniform

conditions of surroundings during the day and night, there appears to be a common tendency for the presence of a little more fat in the morning's milk, even when milkings are apart the same length of time.

(6) *Variation of fat content in different portions of milk drawn from the udder.*—The following figures, taken from the writer's records, illustrate the general rule that the first milk drawn contains least fat, the milk last drawn (strippings) being the richest in fat:

	Per cent. of fat in milk		
	COW 1	COW 2	COW 3
First portion drawn	0.90	1.60	1.60
Second portion drawn . . .	2.60	3.20	3.25
Third portion drawn	5.35	4.10	5.00
Fourth portion drawn (strip'gs)	9.80	8.10	8.30

It is also known that the per cent. of fat in milk varies in different quarters of the udder of a cow, and also varies more or less in each quarter with the order in which the teats are milked.

THE NITROGEN COMPOUNDS OF MILK

Some confusion prevails in respect to the names of the nitrogen compounds of milk. They have been spoken of as albuminoids, proteins, etc. Frequently the word casein is erroneously used to include all the nitrogen compounds of milk.

How many nitrogen or protein compounds are present in normal milk? What are they? Different workers have reported from one to seven or more. The chemical evidence at hand justifies us in the belief that normal milk contains, in appreciable amounts, not more than three nitrogen-containing or protein bodies,

viz., casein, albumin and globulin. Globulin is present in so small quantities that we can properly regard casein and albumin as being essentially the nitrogen compounds of milk, when we consider them quantitatively.

Milk-Casein is the most important nitrogen compound in milk, because, (1st) it is the one present in largest quantity; (2d) its presence makes it possible to convert milk into cheese; and (3d) it has a high value as food. Milk-casein is most familiar to us in the form of the solid, white substance called curd, which forms in milk when it sours, though, strictly speaking, this well-known, white substance is not milk-casein, but a closely related compound.

(1) *Composition of milk-casein.*—Casein is a very complex chemical compound, containing the elements carbon, oxygen, hydrogen, nitrogen, sulphur, and phosphorus. In milk the protein molecule of casein is combined with calcium, or some calcium compound, and hence the proper chemical name of milk-casein is *calcium casein.* It exists in milk, not in solution, but in the form of extremely minute, solid, gelatinous particles in suspension. The slime found in the bowl of centrifugal separators consists, to a considerable extent, in milk-casein.

(2) *Action of acids upon milk-casein.*—When milk sours in the ordinary way, the lactic acid formed acts upon the calcium casein, two chemical changes taking place. First, the lactic acid combines with the calcium of the calcium casein, forming calcium-free casein, or simply casein set free from its combination with calcium. When more lactic acid forms, the sec-

ond change takes place, the free casein taking up the acid without definite combination and forming a substance which is familiar as the curd of sour milk. Similar changes occur when milk is treated with other acids, such as hydrochloric, acetic, sulphuric, etc. Free casein is insoluble in water and also in very dilute acids at ordinary temperatures. The action of acids on calcium casein and on free casein is hastened by increase of temperature. Casein dissolves easily in an excess of acid, forming soluble casein salts.

(3) *Action of alkalis on milk-casein.*—Dilute solutions of alkalis (caustic soda, ammonia, etc.) act upon casein and its salts with acids, forming compounds that dissolve easily in water. These alkali compounds of casein are not affected by rennet. Some of these compounds are found in commerce as food and medicinal preparations under such names as Plasmon, Nutrose, Santogene, Eucasein, Galactogene, etc.

(4) *Action of heat on milk-casein.*—Heat alone under ordinary conditions, even at the boiling point of water, does not coagulate the casein in milk. Casein may be coagulated by heating under pressure at a temperature of about 270° F. The browning of milk heated under pressure is more or less due to changes in the casein. The formation of a peculiar skin on the surface of milk heated above 140° F. is largely due to the calcium casein of the milk and not to albumin as was formerly supposed. The skin itself contains practically all of the constituents of the milk and may be regarded as a kind of evaporated milk.

(5) *Action of rennet on milk-casein.*—One of the most characteristic properties of the calcium casein

of milk is its coagulation by the enzym or chemical ferment contained in rennet, which is an extract of the mucous membrane of a calf's stomach. This property makes possible the manufacture of cheese from milk. The curd formed by the action of rennet is called paracasein or, more properly, calcium paracasein. There appears to be only slight chemical difference between calcium casein and calcium paracasein. The coagulation of calcium casein produced by rennet is quite different from that produced by acids. Calcium paracasein behaves towards acids and alkalis much like calcium casein.

(6) *Other changes caused in milk-casein.*—Under the action of chemical reagents, of enzyms and of various organisms, calcium casein and paracasein may be changed into a large number of other substances. Among the compounds and classes of compounds thus formed are paranuclein, albumoses, peptones, amides (crystallizable bodies) and ammonia. These products are never found in normal milk as it leaves the cow, but may be present in milk that has stood some time.

Milk-Albumin.—Milk-albumin differs from milk-casein in composition and behavior. Thus, milk-albumin (1) is not acted upon by rennet; (2) is not coagulated by acids at ordinary temperatures; (3) is coagulated by heat alone, though not completely, above 160° F.; and (4) is in solution in milk.

Milk-Globulin.—This compound is present only in small quantities in normal milk and is of no special importance, so far as known.

In connection with the nitrogen compounds of milk, we will refer briefly to a class of compounds which

have attracted much attention in recent years, namely, milk-enzyms. These are present in very small amounts and have never been isolated in pure forms but they are thought to be nitrogen-containing compounds. They are chemical ferments and have the power of changing other substances without themselves undergoing appreciable change. Methods of ascertaining their presence in milk are given later (pp. 158-163).

Amounts of casein and albumin in milk.—In single milkings of individual cows, the casein and albumin, taken together, vary from 2.5 to 6 per cent. and average about 3.2 per cent. Milk-casein varies in amount from 2 to 4 per cent. and averages about 2.5 per cent. Albumin varies from 0.5 to 0.9 per cent. and averages about 0.7 per cent. The amount of casein in relation to albumin varies greatly. On an average, milk contains about 3.6 parts of casein for one of albumin, or, stated another way, casein forms about 80 per cent. of the nitrogen compounds of milk.

The amount of casein and albumin in milk is influenced by many conditions, such as influence the general composition of the milk, among which are individuality, breed, advance of lactation, etc. As the lactation period advances, there is a general tendency on the part of casein and albumin in milk to increase.

Relation of fat and nitrogen compounds in milk.—In normal milk containing over 3 per cent. of fat, the amount of casein and albumin is rarely greater than the amount of fat, especially in the milk of herds of cows. When the per cent. of fat is less than that of the nitrogen compounds, the milk may generally be regarded as skimmed, especially in the case of milk from herds.

MILK-SUGAR

Milk-sugar, also called *lactose,* is present in cows' milk in solution. In general composition, it resembles ordinary sugar, but it is less sweet and less soluble in water. The amount of sugar in milk varies from below 4 to over 6 per cent. and averages about 5 per cent. Its importance in dairy work, especially in connection with the manufacture of butter and cheese, comes from the ease with which it is converted into lactic acid by certain forms of bacteria. In the ordinary souring of milk, the amount of milk-sugar decreases somewhat more than one-fourth and there is formed as a maximum about 0.9 per cent. of lactic acid. More acid may be formed after some time. Hence, sour milk, when two or three days old, contains only 3.5 to 4 per cent. of milk-sugar. The sugar of milk passes largely into the whey in cheese-making and forms over 70 per cent. of the solids in whey. The milk-sugar of commerce is usually prepared by evaporating whey and purifying the impure product first obtained.

THE SALTS OF MILK

The salts of milk, commonly included under the term "ash," are present in only small amounts, 0.7 per cent. on the average; but they have important relations to milk and its products. Our knowledge of these compounds is very incomplete. The salts of milk are commonly spoken of as the ash or mineral constituents. This conception is somewhat misleading, because the materials appearing in the ash of milk are, to some considerable extent, combined in organic compounds, instead of existing in the milk as separate

inorganic bodies. The ash represents in amount, therefore, more than the so-called mineral constituents of milk and less than the salts of milk. While the ash in milk amounts to about 0.7 per cent., the amount of salts probably approximates 0.9 per cent. A portion of the salts of milk is in solution, including such compounds as calcium citrate, sodium chloride, potassium acid phosphate, etc., while a portion (tricalcium phosphate) appears to be in suspension in the form of very finely divided particles.

THE GASES OF MILK

Milk contains more or less oxygen and nitrogen, these gases being carried into it mechanically from the air in the process of milking. It contains also, when freshly drawn, carbon dioxide, already present in the udder milk, there being probably between 3 and 4 per cent. by volume, a portion of which escapes at once while being drawn from the udder under usual conditions.

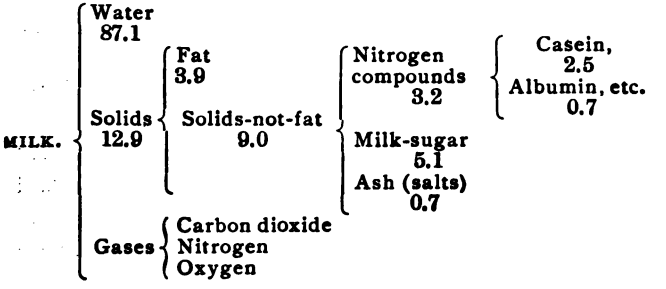
GENERAL SUMMARY

Milk contains water, fat, casein, albumin, sugar, salts, carbon dioxide and some other constituents in small quantities. The fat and casein and some of the salts are in suspension and not in solution, while albumin, sugar and the larger portion of the salts are held in solution by the water.

As a matter of convenience, the compounds of milk are divided into certain arbitrary groups. By one system of division, the compounds of milk are arranged in two classes:—(1) *Water,* and (2) *milk-solids* (or total solids), this second class including

fat, casein, albumin, sugar, salts (ash), etc. Another division is made on the basis of the milk-fat into (1) *fat* and (2) *milk-serum,* which includes all the milk constituents except the fat. Separator skim-milk is nearly pure milk-serum. Then we have the milk-solids subdivided into (1) *fat* and (2) *solids-not-fat* (casein, albumin, sugar, salts (ash), etc.)

The following arrangement shows the general relation of the compounds contained in milk, the figures indicating the percentages present in average milk:



AVERAGE ANALYSIS OF COWS' MILK

	WATER	TOTAL SOLIDS	FAT	CASEIN	ALBUMIN	SUGAR	ASH
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Average of 5,552 American analyses compiled by the author.....	87.1	12.9	3.9	2.5	0.7	5.1	0.7
Average cheese-factory milk for the season (May to Nov.) in N. Y. State...	87.4	12.6	3.75	2.45	0.7	5.0	0.7

REPRESENTATIVE ANALYSES OF PRODUCTS AND BY-PRODUCTS OF MILK

	WATER	TOTAL SOLIDS	FAT	CASEIN	ALBUMIN	SUGAR	ASH
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Butter.....	15.0	85.0	81.0	1.0	....	....	3.0
Cheddar Cheese (green)	36.8	63.2	33.75	23.75[2]	....	....	5.7[3]
Skim-milk (separator)	90.3	9.7	0.10	2.75	0.80	5.25	0.80
Whey.....	93.4	6.6	0.35	0.10	0.75	4.80	0.60
Buttermilk	90.6	9.4	0.10	2.80	0.80	4.40[4]	0.70

[1] Salt. [2] Paracasein. [3] Salt and Ash. [4] .60 per cent. lactic acid in addition.

DEFINITIONS AND STANDARDS OF MILK AND MILK PRODUCTS

The United States Department of Agriculture has established official standards for purity of dairy and other food products, defining also what is meant by the terms used in designating different materials. These definitions and standards have been most carefully worked out by members of the Association of Official Agricultural Chemists, several years having been devoted to the collection of data. The official definitions and standards relating to milk and milk products are as follows:

A. MILKS.

1. *Milk* is the fresh, clean, lacteal secretion obtained by complete milking of one or more healthy cows, properly fed and kept, excluding that obtained within 15 days before and 10 after calving, and contains not less than 8.5 per cent. of solids-not-fat, and not less than 3.25 per cent. of milk-fat.

2. *Blended milk* is milk modified in its composition so as to have a definite and stated percentage of one or more of its constituents.

3. *Skim-milk* is milk from which a part or all of the cream has been removed and contains not less than 9.25 per cent. of milk-solids.

4. *Pasteurized milk* is milk that has been heated below boiling, but sufficiently to kill most of the active organisms present, and immediately cooled to 50° F. or lower.

5. *Sterilized milk* is milk that has been heated at the temperature of boiling water or higher for a length of time sufficient to kill all organisms present.

6. *Condensed milk, evaporated milk,* is fresh, pure, normal milk from which a considerable portion of water has been evaporated and contains such percentages of total solids and of fat that the sum of the two shall not be less than 34.3 and the percentage of fat shall not be less than 7.8.

7. *Sweetened condensed milk* is milk from which a considerable portion of water has been evaporated and to which sugar (sucrose) has been added, and contains not less than 28 per cent. of milk-solids, of which not less than 8 per cent. is milk-fat.

8. *Condensed skim-milk* is skim-milk from which a considerable portion of water has been evaporated.

9. *Buttermilk* is the product that remains when butter is removed from milk or cream in the process of churning.

10. *Goat's milk, ewe's milk, etc.,* are the fresh, clean, lacteal secretions free from colostrum, obtained by the complete milking of healthy animals other than cows,

properly fed and kept, and conform in name to the species of animal from which they are obtained.

B. CREAM.

1. *Cream* is that portion of milk, rich in milk-fat, which rises to the surface of milk on standing, or is separated from it by centrifugal force, is fresh and clean and contains not less than 18 per cent. of milk-fat.

2. *Evaporated cream, clotted cream,* is cream from which a considerable portion of water has been evaporated.

C. MILK-FAT OR BUTTER-FAT.

1. *Milk-fat or butter-fat* is the fat of milk and has Reichert-Meissl number not less than 24 and a specific gravity of not less than 0.905 (40°C.).

D. BUTTER.

1. *Butter* is the clean, non-rancid product made by gathering in any manner the fat of fresh or ripened milk or cream into a mass, which also contains a small portion of the other milk constituents, with or without salt, and contains not less than 82.5 per cent. of milk-fat. By acts of Congress approved August 2, 1886, and May 9, 1902, butter may also contain added coloring-matter.

2. *Renovated butter, process butter,* is the product made by melting butter and reworking, without the addition or use of chemicals or any substance except milk, cream, or salt, and contains not more than 16 per cent. of water and at least 82.5 per cent of milk-fat.

E. CHEESE.

1. *Cheese* is the sound, solid, and ripened product made from milk or cream by coagulating the casein thereof with rennet or lactic acid, with or without the addition of ripening ferments and seasoning, and contains, in the water-free substance, not less than 50 per cent. of milk-fat. By act of Congress, June 6, 1896, cheese may also contain added coloring matter.

2. *Skim-milk cheese* is the sound, solid and ripened product made from skim-milk by coagulating the casein thereof with rennet or lactic acid, with or without the addition of ripening ferments and seasoning.

3. *Goat's-milk cheese, ewe's-milk cheese, etc.,* are the sound, ripened products made from the milks of the animals specified, by coagulating the casein thereof with rennet or lactic acid, with or without the addition of ripening ferments and seasoning.

F. ICE-CREAMS.

1. *Ice-cream* is a frozen product made from cream and sugar, with or without a natural flavoring, and contains not less than 14 per cent. of milk-fat.

(2) *Fruit Ice-cream* is a frozen product made from cream, sugar, and sound, clean, mature fruits, and contains not less than 12 per cent. of milk-fat.

3. *Nut ice-cream* is a frozen product made from cream, sugar, and sound, non-rancid nuts, and contains not less than 12 per cent. of milk-fat.

G. MISCELLANEOUS MILK PRODUCTS.

1. *Whey* is the product remaining after the removal of fat and casein from milk in cheese-making.

2. *Kumiss* is the product made by the alcoholic fermentation of mare's or cow's milk.

CHAPTER II

Methods of Sampling and Preserving Milk

Too much emphasis can not be placed upon the importance of taking for analysis a sample of milk that truly represents the whole body of milk from which the sample is taken. This statement applies equally to any product or by-product of milk that is to be tested. Before a sample for testing is taken, the body of milk from which the sample is to be drawn should be uniform throughout in composition. Several conditions may disturb the desired uniformity of composition of a mass of milk, among which are the following:

(1) Separation of fat.
(2) Partial churning of fat.
(3) Freezing of milk.
(4) Souring of milk.

SAMPLING MILK WHEN FAT HAS SEPARATED

The rapidity with which fat-globules rise to the surface of milk in the form of cream is well known. Therefore, milk standing at rest soon loses its uniformity of composition, the upper layers containing more fat than the lower ones. On this account it is always necessary, just before taking a sample of milk for testing, to make sure that the body of milk to be tested has an even composition throughout.

Milk in which fat separation is slight.—In milk

in which there is no visible separation of cream, evenness of mixing may be best effected by pouring the milk from one vessel to another several times immediately before each sample is drawn for testing. Stirring milk, as with a dipper, is less effective than pouring.

Milk in which fat separation is marked.—In milk in which the cream has separated in a visible layer, the pouring needs to be done a greater number of times than in cases where the separation of cream is not noticeable; and, in order to prevent possible churning of particles of cream, the agitation should be as gentle as may be consistent with thorough mixing.

Milk containing dried cream.—In cases where the cream is somewhat dried or hardened, the milk should be warmed to 105° or 110° F. for 5 or 10 minutes to allow the cream to melt. The milk is then vigorously agitated and immediately sampled.

SAMPLING MILK WHEN FAT IS PARTIALLY CHURNED

Milk-fat may separate from milk in the form of small butter-granules, as (1) when the mixing or shaking of the sample to be tested is done too violently; (2) when milk in cans is excessively agitated in transportation; and (3) when bottles, partly full of milk, are sent by mail or express. In such partially churned milk it is difficult to get a representative sample, and the results of testing are, at best, only approximate, unless special measures are resorted to in sampling.

Distributing fat by warming.—In the case of par-

tially churned milk, the fat may be redistributed in the milk by warming it to 105° or 110° F. long enough to melt the butter-granules, after which the sample is vigorously shaken, until the fat is evenly distributed through the milk, and then the sample is drawn at once for analysis.

Dissolving fat in ether.—Another method of treating partially churned milk, previous to sampling, is to shake the milk with 5 per cent. of its volume of ether until the fat-granules are redissolved and then, after further vigorous shaking, to take the sample at once. In this case it is necessary to make a correction by adding to the results 5 per cent. or one-twentieth of the result obtained. For example, a milk, treated with 5 per cent. of ether, and giving, on testing, 3 per cent. of fat, should have added .15 (5 per cent. of 3), making the corrected result 3.15 per cent. When ether is used, extra care must be observed in mixing the acid and milk, (see p. 62) as the heat developed may cause the ether to boil up out of the neck of the test-bottle.

Measures for preventing the churning of fat in milk.—It is better to prevent the churning of fat in milk than to be put to the extra trouble required to get a good sample from milk that has in it fat-granules. Cans of milk, when necessarily exposed to much motion in transportation, should be made as nearly full as possible. In the case of bottles of milk sent by mail or express for analysis, the churning of fat may be prevented in the following manner: Fill the bottle full of milk to overflowing. Then push in tightly a stopper of cork or rubber in which has been made

from top to bottom a hole one-eighth inch in diameter or less. Finally, push a close-fitting plug of wood or a glass rod into the hole in the stopper.

SAMPLING FROZEN MILK

Frozen milk is of very uneven composition in different portions of its mass. The crystals of ice contained in it consist largely of water, while the liquid portion contains most of the milk-solids. In such cases it is necessary to melt the frozen portion by warming, and then to mix well by gentle pouring from one vessel to another, after which the sample is at once taken for testing.

SAMPLING MILK COAGULATED BY SOURING

A sample of thickened, sour milk can not, without special treatment, be taken so as to give reliable results in fat determination. In ordinary curdled milk the percentage of fat remains unchanged in amount, but it is not evenly distributed through the milk. In order to overcome this difficulty, the coagulated substance must be dissolved before sampling. This is done by adding to the milk a strong solution of caustic soda or potash (lye), or strong ammonia water, to the extent of 5 or 10 per cent. of the volume of the milk used for sampling. The alkali is shaken with the milk until the mixture becomes completely liquid, after which the sample is at once drawn for testing. It is necessary to make a correction by adding to the results 5 or 10 per cent. of the amount of fat found, according to the amount of alkali solution used. In place of using a solution of alkali, one can add, in

small portions at a time, finely powdered caustic soda or potash, allowing the milk to stand some time after each addition of powdered alkali and shaking vigorously, the additions of alkali and the agitation being continued only until the milk becomes completely liquid. In using the alkali in solid form, no correction of results needs to be made. The alkali solution or tablets described on page 142 may be used. A darkening of the milk by alkali may occur without affecting the results of the test. In testing, caution must be observed when adding sulphuric acid (see p. 60) to milk in which an alkali has been used, since an unusual degree of heat is produced and the contents of the test-bottle may spurt out. The acid must be added slowly and mixed with the milk much more deliberately than usual.

COMPOSITE SAMPLING OF MILK

Composite samples of milk.—A mixture of daily samples of milk, taken from day to day for several days in succession, is known as a composite sample. In commercial work at creameries, cheese-factories, milk-shipping stations, etc., where the number of patrons is large, a daily test of the milk for its fat content is impracticable. To obviate the great amount of work involved in making daily tests, a jar is provided for the milk of each patron and in this jar is placed a sample of each day's milk, when it is delivered, these daily samples being mixed and allowed to accumulate for a period of one or two weeks. A determination of fat in such a composite sample gives the average percentage of fat in the milk for the period covered

by the mixture of daily samples. This method has been proved to be as accurate as that of testing each sample daily by itself, but there are several precautions to be observed carefully in applying this method in commercial practice.

The conditions that are necessary for success in using the method of composite sampling may be considered under the following heads: (1) Systematic

FIG. 1
COMPOSITE-SAMPLE JAR

FIG. 2
COMPOSITE-SAMPLE JAR

preparation, (2) methods of taking daily samples, (3) use of preservatives, (4) care of composite samples, (5) age of composite samples, and (6) preparation of composite samples for sampling and testing.

Systematic preparation for taking composite samples.—A round glass jar or bottle, holding a pint or quart, should be provided for each patron. The forms given in Figs. 1 and 2 are suitable, or ordinary Mason

fruit-jars may be used. Whatever form of composite-sample jar or bottle be used, the stopper or cover should fit perfectly tight, so as to prevent any possible evaporation of water from the sample of milk, and care should be taken to keep the covers or stoppers tight. Each sample-bottle or jar should be labeled with a name or number easily identifying the patron furnishing the milk. The jars should be arranged in definite order on a rack (Fig. 3), placed conveniently near the point where the milk is delivered. As explained later, some preservative is used in each jar.

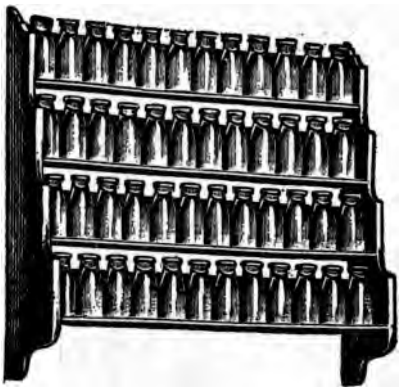


FIG. 3—RACK FOR COMPOSITE SAMPLES

Taking daily samples for composite samples.—Each day when milk is delivered, the sample should be taken immediately after the milk has been poured into the weighing can before weighing, and should then be placed at once in the composite jar or bottle prepared for it. Two methods of sampling are in common use, (1) by means of a small dipper, and (2) by means of a sampling-tube.

(1) *Taking sample with dipper.*—A half-ounce dipper (Fig. 4) is used for taking the sample from the weigh-can, as soon as the milk is poured in. The

sample is at once placed in its proper jar or bottle. Providing the milk is thoroughly mixed in the weigh-can and the quantity of milk delivered by a patron

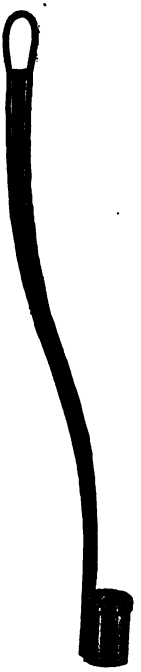


FIG. 4
SAMPLING-DIPPER

FIG. 5
SCOVELL SAMPLER

FIG. 6
EQUITY SAMPLER

from day to day does not vary much, this method of sampling gives correct results.

(2) *Taking sample with sampling-tube.*—There are different types of sampling-tubes (Figs. 5 and 6), of which the Scovell sampler is one of the best. In this

instrument the main tube is open at both ends, the lower end closely fitting into a cap furnished with three elliptical openings. When the sampler, open at the bottom, is let down into a can of milk, the liquid pours into the openings and fills the tube to the height of the milk in the can. When the cap comes in contact with the bottom of the can, the tube slides down and closes the openings, after which the tube can be withdrawn and its contents emptied into the composite jar.

The tube method of sampling possesses two marked advantages over the dipper method: (1) It always takes an aliquot portion, or uniform proportion, of the milk, representing a small column of the milk from top to bottom; and (2) it provides a strictly representative sample of the milk, even when sampling is delayed, because it takes a uniform amount from each layer of milk, going from top to bottom.

THE USE OF PRESERVATIVES IN COMPOSITE SAMPLES

The successful use of composite samples is made possible only by the presence of some substance which will keep the milk from curdling. Three preservatives have been found especially useful for this purpose: (1) Corrosive sublimate, (2) formalin, and (3) bichromate of potash.

Corrosive sublimate, known chemically as mercuric chloride, has the advantage of being a more powerful antiseptic than the other substances, much smaller quantities being effective in keeping milk longer, but it has the disadvantage of being a violent poison.

When this is used as a milk preservative, it is a wise precaution to add a little coloring matter to the milk in order to warn every one of its abnormal character. Corrosive sublimate, mixed with coloring matter, is put up in convenient tablet form and has found extensive use in preserving composite samples. All things considered, it is probably the most satisfactory of the preservatives commonly employed.

Formalin is a liquid containing about 40 per cent. of the chemical compound known as formaldehyde. It is an effective antiseptic and has the advantage of being in liquid form. One cubic centimeter of formalin should keep a pint or quart sample of milk two weeks or more. Formalin possesses the disadvantage of so hardening the milk-casein that it is not as readily dissolved by sulphuric acid (see p. 63) as is the casein of untreated milk. An excessive use of corrosive sublimate may produce a similar hardening of casein.

Bichromate of potash, also called potassium bichromate, is extensively used in preserving samples of milk for testing. It is best to use it in powdered form. It has the following advantages: (1) It is comparatively inexpensive. (2) It colors milk yellow and thus shows its presence. (3) It is not a very violent poison, though not entirely harmless. (4) It is efficient in keeping milk for one or two weeks. However, it has some disadvantages as a preservative of composite samples of milk: (1) If too much bichromate is used, the solution of the casein in sulphuric acid is somewhat difficult and the final results of testing may not be clear. (2) In hot weather, it is often difficult to keep samples without using an excessive amount of

bichromate. (3) Lactic acid in milk considerably reduces the efficiency of bichromate in preserving milk, (4) Samples of milk preserved with bichromate are apt, when exposed to light, to form a tough skin on the surface, which interferes with proper sampling; this can be largely decreased by keeping samples in bottles of amber or brown-colored glass. (5) The presence of bichromate in milk interferes with other tests, such as acidity, specific gravity, detection of formalin, enzyms, freezing-point and refractive index.

The amount of potassium bichromate to be used in composite samples is about 8 or 10 grains for half a pint to a pint of milk. The bichromate is put up for sale in tablets of convenient size, ready for use in preserving milk samples. Bichromate can be satisfactorily used even in hot weather, if the samples are kept in a dark, cool place most of the time.

CARE OF COMPOSITE SAMPLES

In caring for composite samples of milk or cream, some special precautions must be observed. (1) Composite sample jars must be kept covered tight to prevent evaporation of water, which would result in giving a test for fat higher than the correct amount. (2) They should be kept in a cool place, so that the smallest possible amount of preservative will need to be used. (3) They should be kept in the dark most of the time, since direct sunlight may cause the formation of a tough cream, rendering difficult the taking of a good sample for testing. (4) When the daily sample of milk is added to the composite

sample, the contents of the jar should be mixed by giving the jar a gentle, rotary motion. Unless this is done regularly each day, the cream that rises becomes tough, especially where it is in contact with the sides of the jar, and this condition makes it difficult to get a proper sample for testing. This daily mixing also insures the complete solution and distribution of the preservative through the milk, which is an essential condition of success in keeping samples. (5) If a composite sample shows any dried or churned cream, the sample should be warmed to 105° or 110° F. for some minutes and then agitated vigorously before drawing the sample for testing.

AGE OF COMPOSITE SAMPLES WHEN TESTED

It is advisable to make the fat-test in composite samples, when they have been accumulating for a week or ten days. In any case the limit should be placed at two weeks. The custom practised by some of testing composite samples only once a month should be severely condemned. When samples are kept longer than two weeks, it is more difficult to get a perfectly reliable test for fat.

PREPARATION OF COMPOSITE SAMPLES FOR SAMPLING AND TESTING

When a composite sample is to be tested, it is treated like any other sample previous to taking the sample for testing, as has already been described in the first part of this chapter on pp. 20-24.

CHAPTER III

The Babcock Test—Description of Apparatus and Material

The Babcock test is a method for ascertaining the amount of fat in milk and milk products. It was devised by S. M. Babcock, Ph.D., chief chemist of the Wisconsin Agricultural Experiment Station, and was first made public in 1890. There are in use, especially in Europe, other tests, which are more or less imitations or modifications of the Babcock test, such as the Gerber test or acid-butyrometer and DeLaval's butyrometer.

The Babcock test solved the problem of a rapid, accurate, inexpensive and simple method of testing milk and milk products for fat, and it has found extensive application in many lines of dairying, as may be shown by mention of the following important results coming from its use: (1) The payment for milk according to its fat content has been made practicable. (2) Makers of butter and cheese have been able to detect and prevent abnormal losses of fat in the process of manufacture. (3) It has enabled milk producers to detect unprofitable cows, thus furnishing an intelligent guide in improving their herds. (4) It has done more than any other means to stop the watering and skimming of milk in connection with creameries and cheese-factories. (5) It has been of great service in scientific dairy investigations and has, in general, been a source of educational inspiration.

PRINCIPLES AT BASIS OF BABCOCK TEST

This method is based on the action of two agents: (1) the action of strong sulphuric acid upon the constituents of milk-serum, and (2) the action of centrifugal force.

Action of sulphuric acid in Babcock test.—The sulphuric acid used in the Babcock test performs, at least, three functions, which we will consider briefly.

(1) *Action on serum-solids of milk.*—Strong sulphuric acid acts chemically and physically upon the milk-serum solids (casein, sugar, albumin and salts) in such a way as to destroy that strong mechanical, adhesive influence exerted by the milk-serum solids, which tends to prevent the fat-globules separating from the form of an emulsion. When this influence is overcome, the fat-globules are more free to collect in a mass.

(2) *Heat furnished by action of sulphuric acid.*—The action of sulphuric acid upon the water of milk-serum and also upon the organic solids of the serum generates so much heat that the fat-globules easily lose their individuality and run together, a condition favoring rapid separation of fat from serum.

(3) *Specific gravity of serum increased by sulphuric acid.*—The sulphuric acid, being nearly twice as heavy as milk, increases the difference in specific gravity between the milk-fat and the liquid surrounding it. The milk-fat, being much lighter, more readily rises to the surface of the heavy liquid.

Action of centrifugal force in Babcock test.—The action of the sulphuric acid having released the milk-fat largely from the form of an emulsion in the milk-

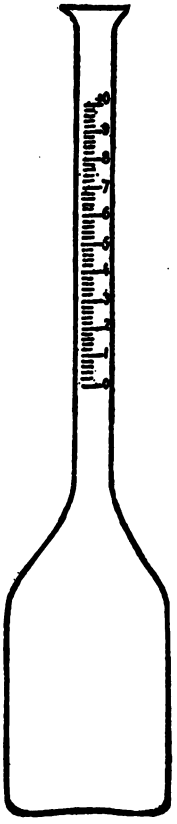
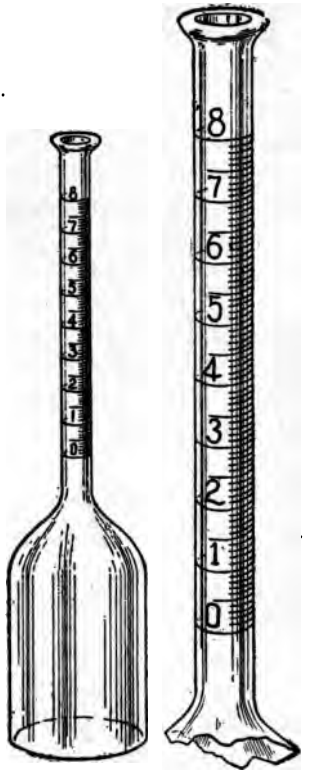


FIG. 7
MILK-TESTING BOTTLE



TEST-BOTTLE 8% MILK

FIG. 7a
NECK SHOWING GRADUATION OF 8% MILK-TEST BOTTLE

serum, the completion of the separation of fat is effected by centrifugal force. When the bottles containing the mixture of milk and acid are whirled, the centrifugal force acts more strongly upon the heavier portion, that is, the mixture of acid and milk-

FIG. 8
PIPETTE

serum. Hence this heavy mixture is forced to the outside, which is the bottom of the bottle, while the much ligher fat is forced to the top. A small amount of fat (.1 to .2 per cent.) remains unseparated under usual conditions.

The following apparatus and material are used in making the tests (1) Test-bottles, (2) pipette for measuring milk, (3) acid-measure, (4) tester or centrifugal machine, and (5) sulphuric acid.

TEST-BOTTLES

The usual forms of bottle used in testing milk are shown in Fig. 7 and 7a. The neck of the bottle is marked with a scale so graduated that each small division represents .2 per cent. and five of these divisions, making one large division, represent 1 per cent., when we use 17.5 cc.* or 18 grams of milk. The marks extend from 0 to 8 or 10 per cent. Why do these divisions represent exact percentages by weight of fat in milk, when no weighing is done in testing milk? We use, in testing, 17.5 cc. of milk, which is known to weigh almost exactly 18 grams. The graduated portion of the neck of the test-bottle is made to hold

*cc. is the abbreviation for *cubic centimeters* (see p. 273).

exactly 2 cc. between the 0 and 10 marks. Since 1 cc. of pure milk-fat is known to weigh .9 gram, 2 cc. of milk-fat, the amount required to fill the neck between the 0 and 10 marks, weighs 1.8 (.9×2) grams, which amount is just 10 per cent. of the 18 grams of milk sample used in testing.

In the form shown in Fig. 7a, which is coming into common use, the scale is limited to 8 per cent., while the smallest divisions measure 0.1 per cent. (See p. 275).

The divisions on the neck of the test-bottle should be accurate and uniform; the lines should run straight across the neck and not obliquely. When the marks and numbers become indistinct from use, they can be rendered clear by rubbing the scale over with the lead of a pencil or with a cloth having on it a little printer's ink or black paint. When in use, each bottle should be numbered or labeled in a distinctive way.

MILK-MEASURING PIPETTE

The form of pipette in common use is shown in Fig. 8. Other forms are shown in Figs. 9 and 10. The pipette should hold 17.6 cc. when filled to the mark. Since about .1 cc. of milk will adhere to the inside, such a pipette will furnish a sample amounting to 17.5 cc. of milk, which weighs about 18 grams, 1 cc. of milk weighing about 1.03 grams on an average. The accuracy of the test, so far as regards the amount of sample taken, depends upon the exactness of the pipette in holding 17.6. The mark on the stem should, for convenience, be two inches or more from the up-

per end of the pipette. The hole forming the outlet should be of such a size as to allow the contents of the pipette to flow out in 5 to 8 seconds. (See p. 277).

MEASURE FOR ACID

A cylinder of glass, like that shown in Fig. 11, with a lip to pour from and a single mark at 17.5 cc., is the form commonly used. Other forms are shown in Figs. 12 and 13. These latter forms, made so as to hold enough acid for 20

FIG. 9
AUTOMATIC PIPETTE

FIG. 10
WAGNER'S PIPETTE

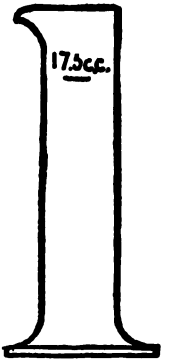


FIG. 11
ACID-MEASURE

or more tests, are probably the most convenient where many samples are to be tested at the same time.

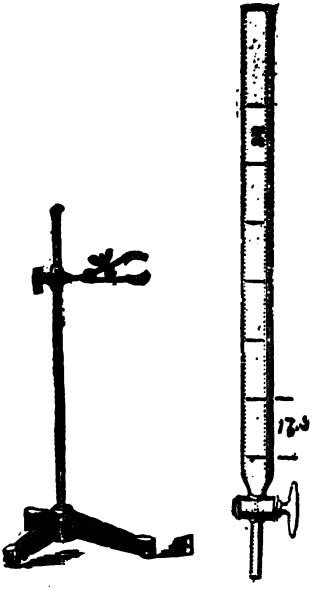


FIG. 12
ACID-BURETTE AND STAND

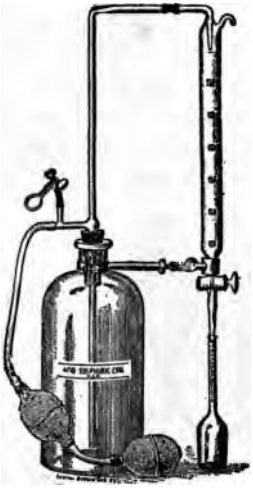


FIG. 13
AUTOMATIC BURETTE

THE CENTRIFUGAL MACHINE, OR TESTER

The centrifugal machine used in the Babcock test is commonly called the Babcock tester. Various forms have been devised, varying in size from those adapted for a single duplicate test up to the needs of large factories. The designs of recent years are much superior to the early forms. Some of the different types are

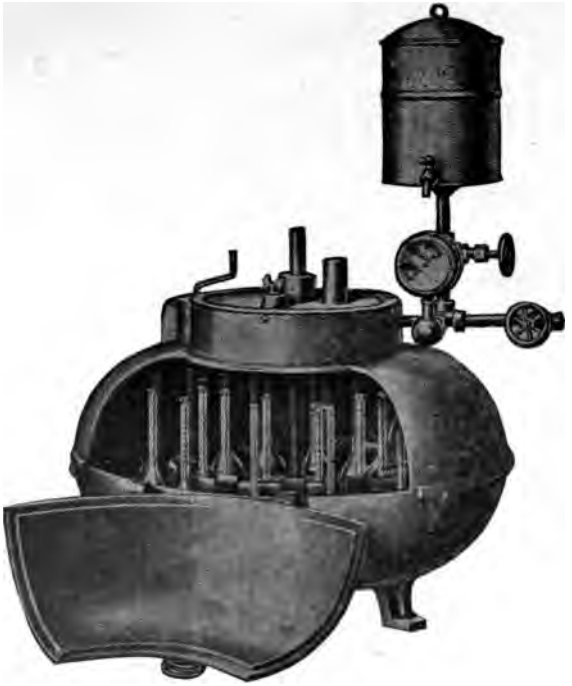


FIG. 14—STEAM-TURBINE TESTER

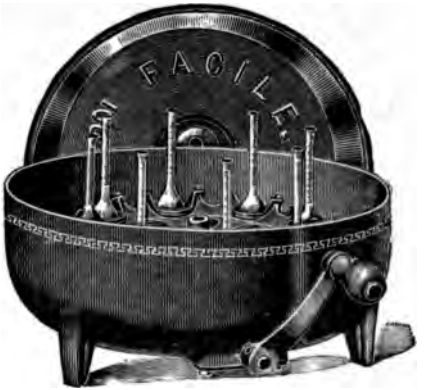


FIG. 15—HAND-TESTER

represented in Figs. 14, 15, 16 and 17. In general they all consist of a revolving disc placed in a horizontal position, and provided with swinging pockets,

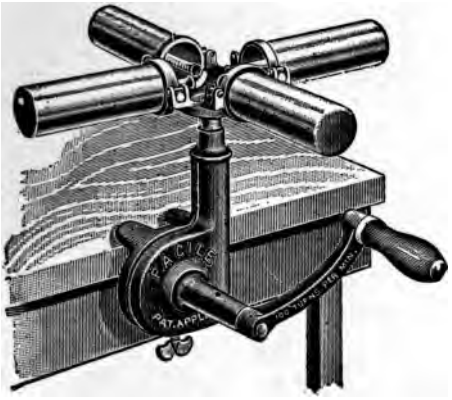


FIG. 16—SMALL HAND-TESTER

in which the test-bottles are placed. When at rest, the pockets hang down, permitting the bottles to stand upright. When the disc is in motion the pockets swing out, carrying the bottles to a horizontal position, the necks of the bottles being directed in toward the center. The testers should be made to carry an even number of bottles. The steam-turbine tester is the best form of centrifugal for factory work. It has the advantage of maintaining a uniform rate of speed and, in addition, the contents of the bottles are kept hot, and hot water is supplied. In some forms, in which the exhaust steam is not carried away and in

which no dampers are provided in the cover, the steam testers may heat the fat too high. For use on farms, hand-testers are available. It is always necessary that

FIG. 17—ELECTRIC CENTRIFUGAL MACHINE OF LATEST DESIGN FOR USE IN BABCOCK TEST

Capable of unusually high speed—safe, accurate and convenient. Made by International Instrument Co. Cambridge, Mass.

the tester should be securely fastened to a firm foundation and so set that the revolving disc is level. The centrifugal should run smoothly, without jar or tremble, when going at full speed.

Estimating speed of centrifugal tester.—In order to cause separation of the most fat possible, the centrifugal disc must move at a sufficient speed. The required number of revolutions depends upon the diameter of the disc, to the edge of which the test-bottles are

attached. The smaller the wheel, the greater must be the number of revolutions a minute.

Farrington and Woll have prepared the following table, showing the necessary number of revolutions for different sizes of testers:

DIAMETER OF WHEEL IN INCHES	*No. of revolutions of disc per minute*
10	1074
12	980
14	909
16	848
18	800
20	759
22	724
24	693

In the case of steam-turbine testers, they are, or should be, made to run at the desired speed under a definite head of steam. These testers should always be provided with a pressure-gage, and a speed-indicator is also desirable.

In the case of hand-testers, the speed can be ascertained in the following manner: Give the handle one full turn and count the number of times a given point on the disc goes round. Suppose, for example, that the diameter of the disc is 16 inches and that it revolves 14 times for one turn of the handle. Such a disc ought to revolve 848 times per minute according to the preceding table. The handle must be turned around as many times a minute as 14 is contained in 848 in order to attain the desired speed, which is found to be about 60 times, or once a second. Then, with watch in hand, regulate the turning of the handle until it

is made to turn 60 times a minute. The proper speed once attained should be kept up during the testing of a sample. The efficiency of whirling can be further tested by treating different samples of the same milk at different rates of speed, the highest per cent. of fat beyond which there is no increase, showing the right speed.

KIND OF ACID USED IN BABCOCK TEST

The acid used in the Babcock test is commercial sulphuric acid, commonly known as oil of vitriol. It should not be quite as strong as the strongest commercial acid. While the strong acid has a specific gravity of about 1.84, the acid used in the test should be between 1.82 and 1.83 at 60° F.

Effect of weak acid.—If the acid is weaker than that indicated by specific gravity 1.82, there is danger that some of the coagulated casein may not be completely redissolved and this, mixing with the fat, makes the fat-column in the test-bottle more or less pale and cloudy, when it should be clear and usually golden yellow in color. In addition, there is apt to be a collection of cloudy matter at the foot of the fat-column, obscuring the line of division and making sharp reading difficult. The use of more than 17.5 cc. of acid not too weak may give good results.

Effect of too strong acid.—When the acid is too much above specific gravity 1.83, the fat-column is dark in color. There is a layer of black material below it, and the amount of fat is difficult to read with accuracy. When the acid is too strong, it is possible to secure accurate results by using less than 17.5 cc.

of acid, the exact quantity being determined by trying different amounts of acid, until the fat-column obtained is clear and yellow. Strong acid, if allowed to stand open to the air, will in time absorb enough moisture to reduce it to proper strength. By far the best plan is to purchase the acid of guaranteed specific gravity 1.82 to 1.83, since all dairy-supply houses now furnish such acid, and then take pains to keep the acid in tightly stoppered bottles when not in use.

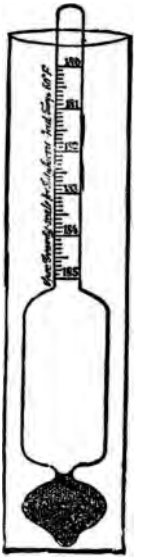


FIG. 18
HYDROMETER FOR TESTING STRENGTH OF SULPHURIC ACID

Testing strength of acid.—The strength of sulphuric acid may be conveniently tested by a specially designed hydrometer (Fig 18). This instrument or acidometer is simply allowed to float in the sulphuric acid, which must be at 60° F., and the specific gravity is read from the scale where it coincides with the upper surface of the liquid, which should be between the scale-marks 1.82 and 1.83. No acidometer should be used whose accuracy is not reliably guaranteed.

Reducing the strength of strong acid.—With the aid of an acidometer, it is possible to purchase strong sulphuric acid and dilute it to proper strength. This is not advised for the average worker. When this is done, extreme caution must be used in diluting the acid. Never pour water into strong sulphuric acid, but always add the acid to the water. The amount of

dilution depends upon the strength of the acid used. One should start with a small dilution and increase gradually until the specific gravity of the acid becomes 1.82 to 1.83. After diluting the acid with water, the mixture becomes hot, and it is necessary to allow it to cool to 60° F. before testing with the acidometer.

Useful indications regarding strength of acid.—After one has acquired some skill in making the Babcock test, one can readily tell whether the acid is too strong or too weak from its action when mixed with milk in the test-bottle. One bases his judgment on the rapidity with which the milk-casein is coagulated and redissolved, and also upon the quickness with which, and the degree to which, the mixture of acid and milk turns dark.

Keeping acid from air.—The acid should be kept in tightly stoppered bottles, because, if exposed to air, it absorbs moisture and becomes too weak. The stopper should be glass, since a common cork stopper is soon destroyed by the acid, and even rubber is not long satisfactory.

Care in handling sulphuric acid.—Strong sulphuric acid is extremely corrosive and is dangerous to handle except with care. In contact with articles like clothing or leather, it quickly ruins them, while on the skin it causes serious burns in a short time. If sulphuric acid gets upon one's skin, it should be immediately and thoroughly washed with an abundance of water, and this may be followed by washing with dilute ammonia or sodium carbonate. In case acid gets on the clothing, treat it first with abundance of water and then with ammonia. Red discoloration on cloth-

ing caused by acid may be remedied by treatment with ammonia, if not too long delayed. Acid on tables, floors, etc., may be neutralized by treatment with washing soda or other alkali.

METHODS OF TESTING ACCURACY OF APPARATUS

The correctness of the graduation of the glassware used in the Babcock test is a fundamental condition of accuracy in the results obtained. In some States all graduated glassware used in the Babcock test must be tested by the State and found correct before its use is permitted in commercial operations. Reliable dealers guarantee the accuracy of their glassware, and it is found to be much more reliable than formerly. However, it is a safe precaution always to test new apparatus before using it. Testing graduated glassware is known technically as calibration.

Testing or calibrating bottles.—In the case of standard milk-testing bottles, the error of graduation should not exceed 0.1 per cent. at any point of the scale; in the case of standard cream-testing bottles, the error at any point in the scale should not be greater than 0.5 per cent.

The most reliable method of testing the accuracy of graduated glassware requires an accurate analytical balance with which to weigh out exact amounts of mercury or water (p. 278), but simpler and more rapid methods are available which are sufficiently accurate for practical purposes. Among the methods available for common use are the following: (1) Testing with water, (2) use of special tester or plunger, and (3) testing with mercury.

(1) *Testing with water.*—This is the most satisfactory method when reasonable accuracy is required and when it is desired to test any point of the graduated scale. The only special piece of apparatus required is a burette (Fig. 21) holding 50 cc., accurately graduated to 0.05 or 0.1 cc. A finely-graduated pipette holding 5 cc. or 10 cc. can be used but is less convenient.

The water used is tinged with ink or any convenient colored solution to make easier the reading of the height of the column of water in the neck of the bottle. Alcohol can be used but is less desirable for some reasons.

In this and other methods, the temperature should be the same for the liquid and apparatus used in testing, and for the glassware tested. This is easily managed by having everything at the temperature of the room in which the testing is done.

In detail the method is carried out as follows: First, fill up to the zero mark with the colored water the bottle to be tested. With a strip or coil of blotting-paper or filter-paper, remove any drops of water adhering to the inside of the neck. Then, from the burette run into the bottle any desired amount of the colored water and read the point on the graduated neck to which the water comes. It should read the same as, or within 0.1 per cent. of, the amount of water run out of the burette. For example, in testing an ordinary milk-bottle, the addition of 0.2 cc. of water should fill the neck to the 1 per cent. point; of 0.4 cc. to the 2 per cent. point; of 1 cc. to the 5 per cent point, etc., up to 2 cc. for the 10 per cent.

point. It is often the custom simply to test the scale as a whole, running in 2 cc. of water at once, in which case the upper surface of the liquid should be on a level with the 10 per cent. mark, if the graduation is correct; for proper accuracy, the water should not reach below or above the mark more than 0.1 cc. It is possible that the results may show the scale to be accurate at the 10 per cent. mark and yet be incorrect at some point below. It is, therefore, desirable to apply the test to several different points between the zero and 10 per cent. marks.

In the case of cream-testing bottles, the same operation is performed, but it must be kept in mind that the relation of the volume to per cent. marks is different in 18-gram bottles as compared with 9-gram bottles; each cubic centimeter in the graduated neck of an 18-gram bottle stands for one-half the percentage that it does in a 9-gram bottle; or, stated in another way, each per cent. in an 18-gram bottle represents twice the volume or number of cubic centimeters that it does in a 9-gram bottle. This is shown clearly in the following table:

	In 18-gram bottles	In 9-gram bottles
0.05 cc. equals	0.25 per cent.	0.50 per cent.
0.1 " "	0.50 " "	1.00 " "
0.2 " "	1.00 " "	2.00 " "
0.4 " "	2.00 " "	4.00 " "
0.5 " "	2.50 " "	5.00 " "
0.7 " "	3.50 " "	7.00 " "
1.0 " "	5.00 " "	10.00 " "
2.0 " "	10.00 " "	20.00 " "
3.0 " "	15.00 " "	30.00 " "
5.0 " "	25.00 " "	50.00 " "

(2) *Testing with special bottle-tester.*—The quickest method of testing the accuracy of the graduation of a test-bottle is to use a special device, which is essentially a simple brass plunger (Fig. 19). This instrument is divided into two equal portions, each part being made of such size as to displace exactly one cubic centimeter of liquid. This bottle-tester is used as follows: The test-bottle is filled to the zero mark with milk, or one may use water or, better, wood alcohol, imparting color to the water or alcohol by adding some black aniline or carmine ink. Fill the bottle nearly to the zero mark and then finish with a pipette or dropper, adding a drop at a time just to the mark. Any drops of liquid adhering to the inside walls of the neck must be removed, using conveniently a strip of blotting or filter paper. The tester is then slowly lowered into the neck of the test-bottle until the liquid rises half way between the two sections of the instrument, when the upper surface of the liquid should be at the 5 per cent. mark (Fig. 20), if the scale

FIG. 19
MILK-BOTTLE TESTER

FIG. 20
TESTING ACCURACY OF MILK-BOTTLE

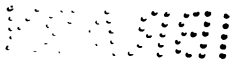
is correct to this point. If the surface of the liquid is above or below the 5 per cent. mark, then that portion of the scale is incorrect to extent shown. After the accuracy of the 5 per cent. mark is tested, the instrument is then lowered into the bottle until the liquid rises about one-eighth of an inch above the top of the upper section of the tester. If the upper surface of the liquid is level with the 10 per cent. mark, the graduation is correct at that point. The graduation of the scale is supposed to be correct, if the tester shows the 5 and 10 per cent. marks to be correct.

In explanation of the use of this form of bottle-tester, it is to be remembered that the neck of the milk-bottle is so graduated as to hold 2 cc. between the 0 and 10 marks; hence, the volume between the 0 and 5 marks should be 1 cc., and that between the 5 and 10 marks should be also 1 cc. The brass plunger is so made that each section displaces, or forces up into the neck, 1 cc. of liquid, the whole instrument displacing 2 cc. This tester, therefore, gives two tests of the scale, one at the 5 per cent. mark and the other at the 10 mark, but does not show the accuracy for any other point.

Some of these instruments are made to test the 4 and 8 per cent. points, so that with two testers, one can, if desired, test the accuracy of the scale at the 4, 5, 8 and 10 points.

In using this bottle-tester the following precautions are to be observed:

(1) Have the upper surface of the liquid exactly on a level with the zero mark in the neck of the test-bottle before putting the tester in.



(2) Clean the inside walls of the neck of the bottle from adhering liquid before testing.

(3) No air-bubbles should be allowed to adhere to the tester when it is below the liquid.

(4) The tester should be dry each time before using.

(5) The temperature of the instrument, liquid and bottle tested should be the same.

(6) While making the test, do not hold the bottle in the hand, because the heat of the hand will produce expansion in the liquid and thus make the results incorrect.

Testers of the same form are made for cream-bottles. Some difficulties are met in their use. In testing bulb-necked bottles, the plunger does not enable one to learn whether the bulb itself has the exact capacity it should. The wire which forms a part of the instrument may interfere with the correct reading of the meniscus. In cream-bottles with narrow necks, it has been found necessary to have the first addition of water reach one-half of the meniscus above the zero mark in order to bring the bottom of the meniscus in the top of the neck on a level with the highest mark of graduation, after the plunger is inserted. In the case of wide-necked bottles, the water should be run into the bottle at the start so that the meniscus is on a level with the zero mark, which then brings the bottom of the meniscus at the top of the neck on a level with the highest mark of graduation, after the plunger is inserted.

(3) *Testing with mercury.*—From an accurately graduated burette measure 2 cc. of clean mercury into the bottle to be tested. Then push down into

the neck of the bottle as far as the top line of graduation a close-fitting cork or plug, cut off square at the lower end. Turn the bottle upside down, causing the mercury to run into the neck. The mercury just fills the space in the neck between the 0 and 10 mark, if the graduation is accurate. The same mercury can be used in the same way in testing one bottle after another by transferring all the mercury from one bottle to another, which may be conveniently done by slipping a piece of elastic, rubber tubing over the ends of the necks of the two bottles. In using the same mercury for testing one bottle after another, no mercury must be lost in transferring, and none must be left in the bottle last tested. The inside walls of the test-bottle must be dry and clean in order to prevent any mercury adhering. (See p. 278).

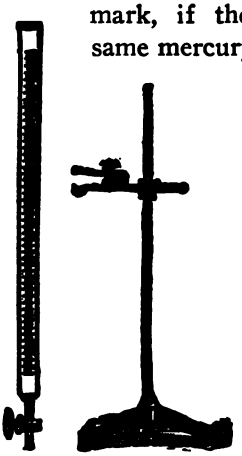


FIG. 21
BURETTE AND SUPPORT

Testing accuracy of pipette.—When many pipettes are to be tested, one runs into one pipette from an accurately graduated burette (Fig. 21), 17.6 cc. of mercury, closing the lower end of the pipette. The mercury should fill the pipette just to the 17.6 cc. mark, if the mark is correct. The same mercury can be transferred to other pipettes in succession. Care must be taken to have the pipettes clean and dry inside and that all the mercury is transferred without loss.

When only one or a few pipettes need testing, water can be used, running from a burette into each pipette 17.6 cc. of water, which should just fill the pipette to the mark, if accurate. (See p. 278).

Testing accuracy of acid measure.—Ordinarily the acid measure does not need testing, since a little variation does not affect the results. When desired, it can be tested by running in water or milk from a 17.6 cc. pipette, known to be accurate.

KEEPING GLASSWARE CLEAN

It is very important that the test-bottles and the pipettes used in the Babcock test should be kept as clean as possible from fat adhering to the inside surface. Unless a special effort is made, the bottles quickly become covered inside with a film of fat, which may be sufficient to increase appreciably the results obtained when the bottles are used in testing. The bottles should be kept entirely free from any fat-film and the wall should be clear and bright. This can be accomplished without serious trouble.

FIG. 22—WASTE-JAR FOR EMPTYING TEST-BOTTLES

As soon as a test is completed and the amount of fat read, the test-bottle, while still warm, should be emptied. This may easily be done by having a large earthenware jar or crock, covered with a board (Fig. 22), in which are several holes large enough to admit easily the necks of test-bottles. The bottle is inverted, the neck run down through one of these holes, and at the same time

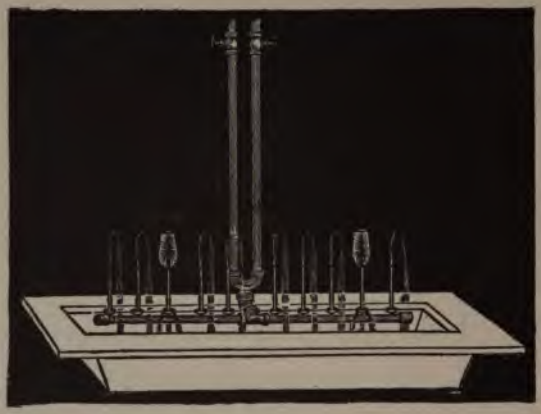


FIG. 23—TEST-BOTTLE RINSER

the bottle is shaken up and down in order to remove the white calcium sulphate deposited on the bottom of the bottle during the test. Then, when one is ready to clean up all the bottles that have been used, each one is rinsed with 8 or 10 cc. of a solution, consisting of one ounce of potassium bichromate dissolved in

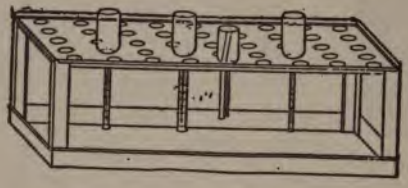


FIG. 24—TEST-BOTTLE DRAINING-RACK

one pint of sulphuric acid. Then a test-bottle brush is run once up and down the neck of each bottle, and finally each is well rinsed with hot water.

There are available several devices which may be found convenient and time-saving where many bottles are used daily. Among these devices may be mentioned a bottle-rinser (Fig. 23), a drain-rack (Fig. 24), and a bottle-washer (Figs. 25*a*, *b*, and *c*), described by Farrington (Bulletin 129, Wis. Agr. Exp. Station, pp. 22-24).

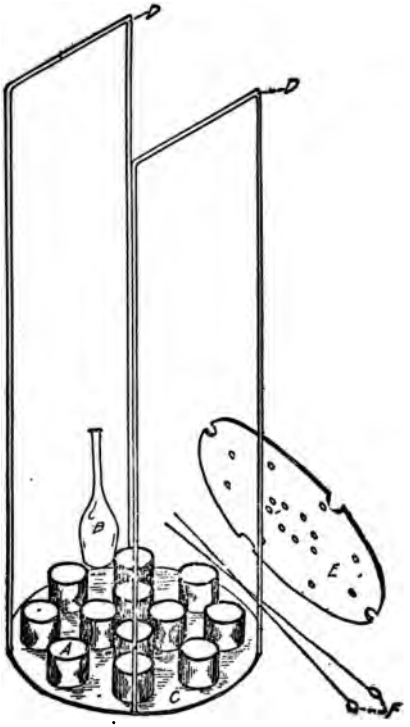


FIG. 25*a*—BOTTLE-HOLDER, EMPTY

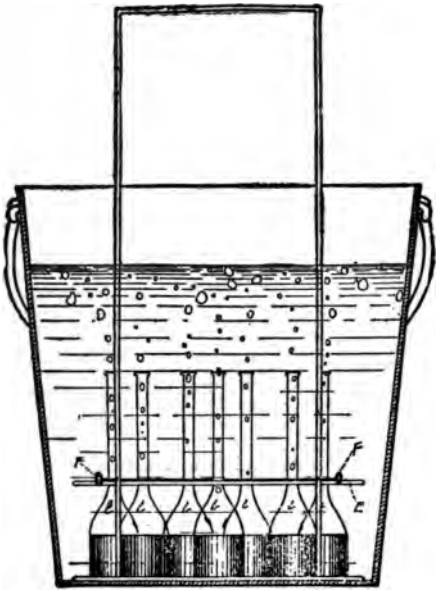


FIG. 25*b*—BOTTLE-HOLDER WITH BOTTLES IMMERSED IN PAIL OF HOT WATER

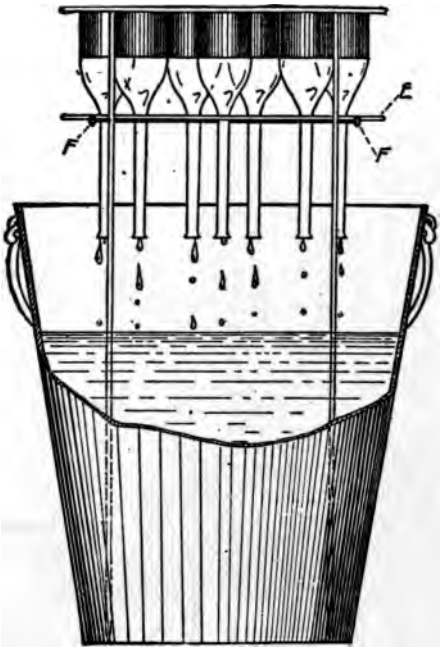


FIG. 25*c*—BOTTLE-HOLDER WITH BOTTLES REVERSED FOR DRAINING

CHAPTER IV

Method of Operating the Babcock Test

In describing the method of operating the Babcock test, when determining the amount of fat in milk, special attention will be called at each step to such difficulties as may occur, and emphasis will be placed upon such precautions as experience has shown to be necessary in order to obtain accurate results.

In brief outline, the different steps may be stated as follows:

1. Mix thoroughly sample of milk, which is at 60° to 70°F.
2. Quickly fill pipette to mark with milk.
3. Run milk into test-bottle.
4. Fill acid-measure to mark with acid and pour into test-bottle.
5. (1) Mix milk and acid thoroughly by rotary motion; (2) let stand 2 to 5 minutes; and (3) mix again.
6. Put test-bottles in tester (centrifuge) and whirl 4 or 5 minutes at proper speed.
7. (1) Add fairly hot water up to neck of bottles; (2) whirl one minute; (3) add hot water to 8 or 9 per cent. mark; and (4) whirl one minute.
8. Read results at temperature of about 130° F.

PREPARING SAMPLES OF MILK FOR TESTING

The milk, which should be at a temperature of 60° to 70° F., is thoroughly mixed by pouring from one vessel to another two or three times, at least, imme-

diately before taking the sample for testing. The special methods of preparing milk for sampling under various conditions are fully considered in Chap. II, p. 20. The fat must be evenly distributed through the milk just before sampling.

Every sample of milk should always be tested in duplicate, that is, two tests should be made at the same time. This insures greater accuracy. If the results of the duplicate test do not agree, there is an error somewhere and the work must be repeated. Also, in case one test is lost and another sample can not be obtained, the remaining test can be used, and the whole work will not be lost.

TAKING SAMPLES OF MILK WITH PIPETTE

The measuring pipette (Fig. 8, p. 35), is filled at once after the thorough mixing of the milk. This is done by placing the lower end of the pipette well down in the milk and sucking up the milk until it reaches a point in the pipette somewhat above the mark around its upper stem. Then the forefinger, *which must be dry,* is quickly placed over the upper end of the pipette before the milk runs down below the mark. By lightening the pressure of the finger on the end of the pipette, the milk is allowed to flow out slowly until its upper surface just reaches the mark on the stem. Some practice is necessary before one can easily and rapidly manipulate the pipette with accuracy.

The pipette must be kept very clean. When samples of several different milks are to be drawn in succession, the pipette may be satisfactorily rinsed by

drawing it full of the milk next to be sampled, this portion being thrown away.

TRANSFERRING SAMPLE OF MILK FROM PIPETTE TO TEST-BOTTLE

Having filled the pipette just to the 17.6 cc. mark, one holds the pipette *obliquely* to the bottle, placing the point of its lower end within the neck and *against the side* of the neck of the test-bottle. The right way of holding the pipette is shown in Fig. 26. By loosening the finger at the upper end of the pipette, one allows the milk to flow slowly down the inside of the neck. The small portion of milk adhering to the inside of the pipette is nearly all carried into the bottle by blowing through the pipette several times before removing it from the neck of the bottle. Not a drop of the milk should be allowed to spill outside the bottle in transferring from the pipette.

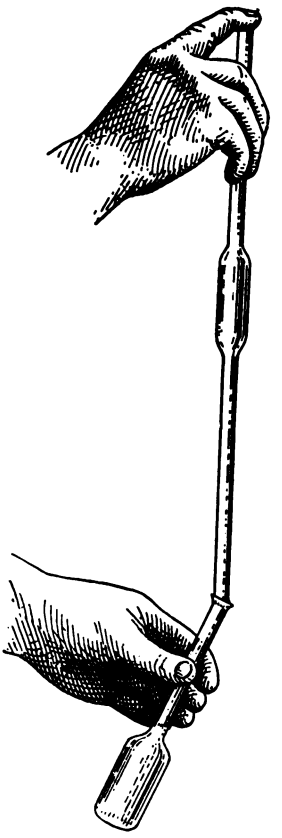


FIG. 26—CORRECT WAY OF HOLDING PIPETTE AND BOTTLE

It is not intended to remove every trace of milk from the pipette into the bottle, since allowance for

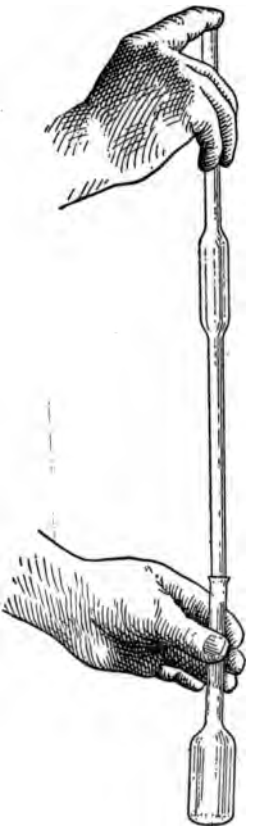


FIG. 26*a*—WRONG WAY OF HOLDING PIPETTE AND BOTTLE

what remains is made in the construction of the pipette. Special experiments having shown that .1 cc. of milk will remain adhering to the inside, the pipette is made to hold 17.6 cc. to the mark, but is expected to deliver into the bottle only 17.5 cc., the exact amount required for the test.

In delivering the milk, the pipette must never be held perpendicularly in a line with the neck of the test-bottle, running the milk straight down as shown in Fig. 26*a*, since the narrow neck may easily choke up with milk and run over the top.

MEASURING AND ADDING ACID

When the samples of milk are in the test-bottles, the acid-measure (Fig. 11, p. 37), is filled to the 17.5 cc. mark and the acid (see p. 43) is poured into the test-bottle. The acid should be at a temperature of 60° to 70° F. Much care must be exercised in pouring the acid into the test-bottle containing the milk. The test-bottle is held in an inclined position, so that the

acid will follow the inside wall down to the bottom, and the pouring should be slow and steady. Thus handled, the acid, being much heavier than the milk, forms a layer by itself at the bottom of the bottle, while the milk forms a separate layer by itself on top of the acid. While pouring in the acid, it is well to turn the test-bottle around slowly so that the acid may in turn come in contact with different portions of the inside walls of the neck and wash down any adhering milk. Unless this is done, some milk may remain on the wall of the neck, in which case it will not be properly acted on by the acid, and the fat-column will contain particles of undissolved casein.

If one attempts to pour the acid straight down the neck of the bottle, two difficulties are liable to occur: (1) The neck may easily choke up and the acid overflow on the operator's hands. (2) The acid may drop into and partially mix with the milk, in which case black particles may appear on the upper surface of the acid layer and later, mixing in the fat-column, may interfere with accurate reading of the results.

Temperature of milk and acid.—It is directed to have the milk and acid at a temperature of 60° to 70° F. before they are placed in the test-bottle. There are good reasons for this precaution. If the milk or acid is decidedly cold, as may easily happen in cold weather, the action of the acid may not be vigorous enough to redissolve completely the coagulated casein, thus producing white specks or a cloudy appearance in and below the fat-column at the end of the test. On the other hand, if the milk or acid is at too high a temperature, as may easily happen in hot weather,

the action of the acid is much the same as if it were too strong, producing dark-colored specks or a darkened appearance in and below the fat-column. Experience shows that when the milk and acid are at a temperature between 60° and 70° F., there is no danger of too slight or too strong action of acid. More acid can be used at lower temperatures and less at higher temperatures with satisfactory results, but this involves experimenting; the best way will be to use the regular amount of acid and regulate the temperature of the milk and acid.

MIXING MILK AND ACID IN TEST-BOTTLE

When the measured amount of acid has been placed in the test-bottle, the acid and milk should be thoroughly mixed. This is best done by giving the bottle a rotary motion, with gentle shaking, until the whole mass becomes liquid and free from solid particles of casein. Much motion up and down should be avoided, since milk might be thrown up into the neck of the bottle beyond reach of the acid, in which case coagulated casein would contaminate the fat-column and impair the results.

When the acid and milk first mix, the casein is coagulated in a somewhat solid mass, which gradually redissolves as the mixing becomes complete. The mixing, once begun, should continue until the casein appears to be redissolved. If the operation of mixing milk and acid is incomplete or is interrupted, black particles may appear in the fat-column at the end of the test.

It is a wise precaution to allow the bottle to stand

2 to 5 minutes after the mixing appears complete and then to agitate a second time with rotary motion just before placing in the tester.

The action of the sulphuric acid upon the water and organic solids of the milk produces a marked degree of heat, as soon as the acid and milk begin to mix. The color of the solution becomes yellow at first and then passes through varying darker shades of yellow to violet, brown and finally dark-brown, if the acid is of the right strength. (See p. 43). The coloration is due to the action of the acid upon the milk-sugar and milk-casein. Too strong acid produces a dense black color. In samples of milk containing too much bechromate of potash, the color becomes greenish black.

Samples of milk that have been preserved for some time with biochromate or formalin, especially when the preservation is used in larger than usual amounts, require more time and agitation to redissolve the coagulated casein than do ordinary samples, since these preservatives harden the coagulated casein. (See p. 29).

WHIRLING THE TEST-BOTTLES

The test-bottles containing the mixture of milk and acid, after being agitated a second time as stated above, are placed in the centrifugal tester (p. 38), and whirled. This is better done soon after the milk and acid are mixed, but it may be delayed without harm for 24 hours, in which case, however, the bottles should be placed in water at 160° to 180° F. for 15 or 20 minutes before whirling.

An even number of bottles should be whirled at the

same time and they should be placed about the disc in pairs opposite to each other, so that the equilibrium of the tester will not be disturbed. When all the samples to be tested are placed in the tester, the cover is placed on the jacket and the machine turned for 4 or 5 minutes at proper speed, 600 to 1,200 revolutions per minute, according to the diameter of the centrifugal disc. (p. 41).

The whirling brings the fat to the top of the mixture in the test-bottle. The whirling of the bottles should never be done without having the cover on the jacket, for two reasons: (1) The cover prevents the cooling of the fat in the test-bottles, and (2) the operator is protected from injury in case a bottle should break and scatter its contents while being whirled.

In the case of hand-testers, it may be necessary to put hot water in the jacket in cold weather in order to keep the bottles warm enough.

ADDING HOT WATER TO THE TEST BOTTLES

When the bottles have been whirled 4 or 5 minutes, moderately hot water is added to each bottle until the contents come to the lower end of the neck. The water may be added with a pipette or by means of any convenient arrangement. The cover of the machine is replaced and the bottles are whirled at full speed for one minute. Hot water is again added to the bottles until the fat, which is lighter than the rest of the liquid, rises in the neck to the 8 or 9 per cent. mark. One must be careful never to raise the fat above the 10 per cent. mark. The whirling is then repeated for one minute at full speed.

Three points deserve attention in this connection: (1) The temperature of the water added, (2) the kind of water used and (3) the number of times water is added.

(1) The temperature of the water added should be above 120° F. The aim in general should be to have the temperature of the fat at the close of whirling at 130° or 140° F., and the temperature of the water added should have reference to this fact. However, any effect of too hot or too cold water can be remedied after the final whirling by adjusting the temperature as needed.

(2) Clean, pure, distilled water is the best form to use and, next, soft rain water. Hard water may seriously affect the results. Objections to hard water may in most cases be overcome by thorough boiling or by previous treatment with a few drops of sulphuric acid.

(3) Some operators add the hot water only once, filling the bottle to near the top of the neck immediately after the first whirling. The advantage of adding the water in two portions is that the fat is washed free from adhering impurities, since the fat-column is often mixed with various particles which render the reading uncertain and frequently too high.

READING RESULTS IN PERCENTAGE OF FAT

After the last whirling is completed, the test-bottles are removed from the tester, one at a time, in order to read the results of the test. To ascertain the amount of fat, hold the test-bottle upright, having the graduated scale of the neck of the bottle on a level

with the eye. Notice the divisions marking the highest and lowest limits of the fat-column. The difference between them gives directly the per cent. of fat in the milk tested. The readings can be made accurately to one-half of a division, that is, to one-tenth of one per cent. Some test-bottles are provided with a regulator which moves the bottom of the fat-column to a level with the nearest numbered mark.

In connection with the measuring of the fat-column, the following points deserve attention: (1) Using dividers to assist in reading, (2) the temperature of the fat-column, (3) the upper and lower limits of the fat-column, (4) the correct appearance of the fat-column, (5) defects in appearance of the fat-column.

(1) If one uses test-bottles not provided with a regulator for adjusting the level of the fat-column, the reading of the percentage of fat on the scale may be made with less liability of error by measuring the length of the fat-column with a pair of dividers, one point of which is placed at the bottom and the other at the upper limit of the fat-column. The dividers are then removed and one point is placed on the zero mark of the scale on the bottle used, when the other point will be at the exact per cent. of fat in the milk tested.

(2) The temperature of the fat, when it is read or measured, should be above 120° F. and not above 140° F., preferably about 130° F. This will insure sharply defined upper and lower limits of the fat-column. In case the contents of the bottles are below 120° F., the bottles should be placed for 15 or 20 minutes in water that has a temperature of 130° to 140° F.,

before the reading is made. This usually needs to be done in cold weather, when hand-testers are used, especially if no hot water has been placed in the jacket during the whirling. If the fat is above 150° F., it should be allowed to cool to 140° F. or below before reading the results. Too high temperatures give too high results, because the fat-column expands.

(3) The line of division between the fat-column and the liquid beneath is nearly a straight line when the testing is properly done, and one need have no doubt about the reading of the scale at this point. But the upper surface of the fat-column is concave instead of straight, which may cause some uncertainty as to the exact point at which the reading should be made on the scale. The correct reading is taken at the line where the upper surface of the fat-column meets the sides of the neck, the very highest point at which the fat-column is seen. The reading should not be made from the dark line or meniscus lower down, which is caused by the refraction of the curved surface. The points at which the readings should be made are shown in Fig. 27, indicated as A and B. Results read this way agree with those obtained by gravimetric analysis. The objection may be raised that we get too high results by reading from the extreme top points of the fat-column, just as if the upper surface were straight at

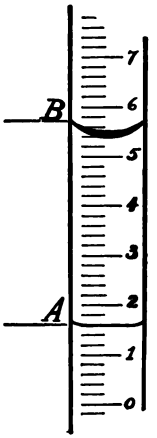


FIG. 27
MEASURING
FAT-COLUMN

these points instead of concave. While there is such an apparent error, the excessive reading thus caused is only enough to make up for the loss of fat which can not be separated from the rest of the liquid by centrifugal force and brought into the fat-column. The amount of fat thus left in the mixture of milk-serum and acid is ordinarily about .2 per cent. and this is about the amount of excess obtained by the approved method of reading the upper limit of the fat-column.

(4) The fat appearing in the neck of the test-bottle at the end of a successful test is of a clear, yellow color, and the line of division between its lower limit and the acid solution beneath it is sharply distinct. However, the fat is apt to be light-colored in the case of milk from cows far along in lactation.

(5) The fat-column may show certain defects, if the conditions of the test have not been properly carried out, among which are (*a*) black particles below or above or in the fat-column, or a darkened appearance of the whole column of fat; (*b*) white particles below or above or in the fat-column, or a cloudy appearance of the whole column; and (*c*) bubbles on the surface.

(*a*) *Black particles* in the neck of the test-bottle at the end of the test, or a darkened appearance of the fat itself, are due to one or more of the following causes: (1) Too strong acid (above 1.83 specific gravity), (2) too much acid (more than 18 cc.), (3) too high temperature of the milk or acid (over 75° F.), (4) allowing milk and acid to stand in test-bottle too long before mixing, (5) allowing the acid to drop

through the milk when poured into the test-bottle, (6) interrupting the mixing of the milk and acid after beginning and before completion. Black particles can usually be prevented by mixing 2 cc. of diluted glycerine (80 cc. of glycerine and 20 cc. of water) with the milk before adding the acid. The difficulty may also be often overcome by using a mixture of equal parts of water and sulphuric acid to fill the bottle after the first whirling.

(*b*) *White* particles of undissolved casein below or above or in the fat-column, or a cloudy appearance of the fat, are due to one or more of the following causes: (1) Too weak acid (below 1.82 specific gravity), (2) insufficient amount of acid (less than 17 cc.), (3) too low temperature of milk or acid (below 60° F.), (4) incomplete mixing of milk and acid, (5) insufficient speed of tester.

Sometimes when the fat is not clear, good results may be obtained by allowing the bottles to cool enough for the fat to harden some, and then warming in water at 140° F. before reading.

(*c*) *Bubbles of gas,* appearing as foam on the top of the fat-column, are generally due to the use in the test-bottle of hard water containing carbonates. This condition may be prevented by adding to the water, previous to use, a few drops of sulphuric acid. When the foam appears and interferes with the reading, a few drops of alcohol are put on the top of the fat-column and the reading is at once made. The alcohol causes the bubbles to disappear and produces a sharp line of division between the fat and alcohol. If the alcohol is allowed to be in contact with the fat for

some time before the reading is made, the alcohol and fat mix and increase the height of the fat-column, thus producing misleading results.

OUTLINE STATEMENT OF SOME SPECIAL PRECAUTIONS

1. Always make tests in duplicate.
2. Make sure that the sample is a representative one.
3. Have the temperature of the milk and acid at 60° to 70° F. before putting in test-bottle.
4. Use only acid of right strength.
5. Mix milk and acid thoroughly as soon as acid is added.
6. Mix a second time after a short interval.
7. Make sure that the tester runs at right speed and does not jar.
8. Use only clean, soft water in filling bottles.
9. Read bottles before they cool and at about 130° F.
10. To insure accuracy, read each test twice.

SOME MODIFICATIONS OF THE BABCOCK TEST

One frequently sees references in dairy literature to other forms of tests for milk. As a matter of information, we will notice a few of the modifications of the Babcock test together with other forms that are in use, giving good results.

The Russian Test.—This is a modification of the Babcock test, differing mainly in respect to some of the mechanical details. A special automatic pipette is used (Fig. 28), a special form of test-bottle (Fig. 28a), the neck being separate from the rest of the bottle, and

also a special form of acid-measure. The pipette and acid-measure are one-half the usual size. The milk and acid are run into the bottle very easily, and the bot-

FIG. 28
AUTOMATIC "RUSSIAN" PIPETTE

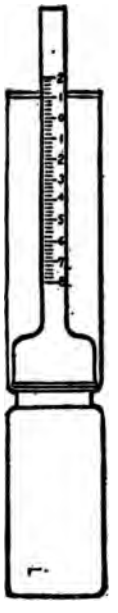


FIG. 28*a*
"RUSSIAN" TEST-BOTTLE

tles are filled with hot water automatically while the machine is in motion, the tester also being of a special form.

The Gerber Butyrometer.—Special forms of tester, test-bottle, etc., are used. The test uses 11 cc. of milk, 10 cc. of sulphuric acid (1.825 specific gravity),

and 1 cc. of amyl alcohol. The operations are carried out about the same as in the Babcock test.

The "Sinacid" (no acid) Test.—The distinctive feature of this test is that, in place of sulphuric acid, it uses a patented mixture, consisting of sodium hydroxide (caustic soda), sodium sulphate, and potassium sodium tartrate (Rochelle salt) which, unlike sulphuric acid, is entirely free from any dangerous properties; it uses also a colored alcoholic solution. After mixing the "sinacid" liquid with the milk, the mixture is heated to 200° F. for 5 minutes before being whirled in the tester. The results do not always appear to agree closely with those given by other tests, according to the reports of some operators. There is, moreover, some natural prejudice against using a process, any part of which is patented.

Gerber's "Sal" Test.—Gerber has described a method in which no acid is used, but a mixture containing sodium hydroxide, common salt and Rochelle salt; in addition a small amount of isobutyl alcohol is added.

Wendler's "New Salt" Method.—A mixture of neutral salts is used consisting of citrate and salicylate compounds.

CHAPTER V

Method of Testing Cream by the Babcock Test

The Babcock test can be used in ascertaining the amount of fat in cream, but certain modifications and precautions are necessary to insure correct results such as (1) special form of test-bottle, (2) particular care in sampling cream, (3) weighing the cream to be used in the test instead of measuring it, (4) variations in some details of the test and (5) special control of the meniscus.

USE OF MILK-TEST BOTTLES IN TESTING CREAM

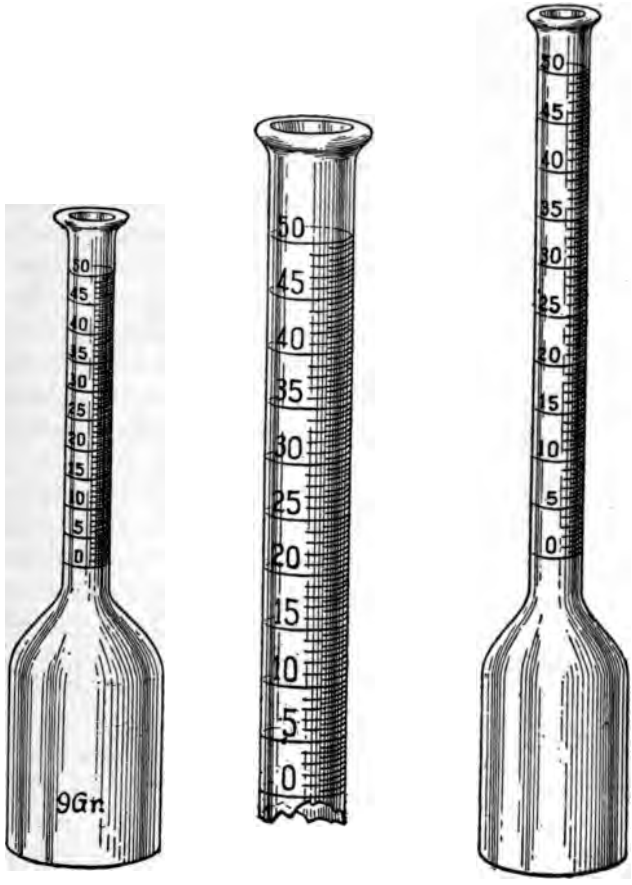
Milk-testing bottles can be used in testing cream only under special conditions. Their use is generally inconvenient and it is only in rare cases that they are ever now employed: Cream containing over 8 or 10 per cent. of fat will fill the neck of the test-bottle too full for measurement, when we take 18 grams (about 17.5 cc.) to test. This difficulty may be overcome in two ways: (1) By using a sample of cream less than 18 grams, and (2) by dividing an 18-gram sample into roughly equal parts between two or more bottles, according to its richness in fat. In the former case the per cent. of fat read is increased by a correction to be considered later (p. 88). In the second case, the tests are made as in case of milk and the percentages found in the different bottles are added, the sum being the per cent. of fat in the cream tested. The

volume of cream in each test-bottle is always made up to about 17.5 cc. by adding water to the cream and mixing before adding acid.

SPECIAL CREAM-TESTING BOTTLES

To test in one bottle an 18-gram sample of cream containing over 10 per cent. of fat, the neck must be made to hold more than the neck of a milk-bottle, that is, more than 2 cc. This additional space must be obtained (1) by using a neck of larger diameter, keeping the length the same as in the milk-bottle or (2) by making the neck longer, keeping the diameter the same, or (3) by furnishing the neck with a bulb of definite capacity.

Different kinds of bottles.—Cream testing bottles differ mainly in the construction of the neck, but in some cases the body of the bottle may vary in shape and size. The neck varies in respect to shape, length, capacity, diameter and fineness of graduation. The principal varieties of cream-testing bottles on the market are included under the following outlined description: (1) The neck is either straight throughout its length or bulb-shaped in one portion. (2) The length of bottle varies, being usually 6 or 9 inches, but special lengths of 6½ and 10 inches are made. (3) The graduated scale measures 20, 25, 30, 40, 50 and 55 per cent., usually corresponding to a capacity varying from 4 to 11 cc. (4) The smallest divisions of the scale vary from 0.2 to 1 per cent. (5) The graduation is directly based on the use of 18 grams of cream in some cases and on 9 grams in others; the latter form is desirable in creamery work.



6½'' 9 GR. 50% CREAM-BOTTLE

NECK SHOWING GRADUATION OF 6½'' 9 GR. 50% CREAM-BOTTLE

9'' 9 GR. 50% CREAM-BOTTLE

FIG. 29—STRAIGHT-NECKED CREAM-BOTTLES

Requirements for bottles.—In the selection of cream-testing bottles, certain points should be kept in mind, such as (1) accuracy of reading, (2) ease of reading, (3) convenience of handling and (4) durability.

(1) *Accuracy of reading.*—The accuracy with which the percentage of fat can be read depends upon (a) the diameter of the neck, (b) the length of the neck and (c) the amount of cream used (9 or 18 grams). The larger the diameter of the neck, other conditions being uniform, the greater is the percentage represented by each division of the scale, and, consequently the less the accuracy of reading. The longer the neck, other conditions being the same, the smaller is the percentage of fat represented by each division and, therefore, the greater the correctness of the reading. The length and diameter of neck being the same, a bottle with neck graduated on the basis of using a 9-gram sample of cream permits more accurate reading than when based on 18 grams. For accurate work, no bottle should be used in cream-testing in which the finest division of the graduated scale represents more than 0.5 per cent.

FIG. 29*a*
STRAIGHT-NECKED CREAM-BOTTLE

(2) *Ease of reading.*—This depends mainly upon the diameter of the neck; the greater the diameter, other conditions being the same, the more difficult is

the reading. In the case of bulb-necked bottles, a special difficulty is introduced because care must be taken, when water is added near the close of the test, so that neither the lower nor upper surface of the fat-column comes within the bulb, making it obviously impossible to read the results without further manipulation.

(3) *Convenience of handling.*—Bottles with shorter necks are more convenient to handle; they are filled and cleaned more easily and rapidly.

(4) *Durability.*—Shorter bottles, when properly made, are more durable. Long-necked bottles are top-heavy and more liable to be overturned in handling. The necks of bulb-necked bottles are more easily broken than straight necks.

Owing to inconvenience of manipulation and to larger breakage, bulb-necked bottles are little used now in comparison with straight-necked bottles.

Best forms of cream-testing bottles.—Several investigations have shown that many of the bottles in use at creameries are wholly incapable of giving sufficiently accurate results. The latest and most exhaustive investigation was carried out by Hunziker

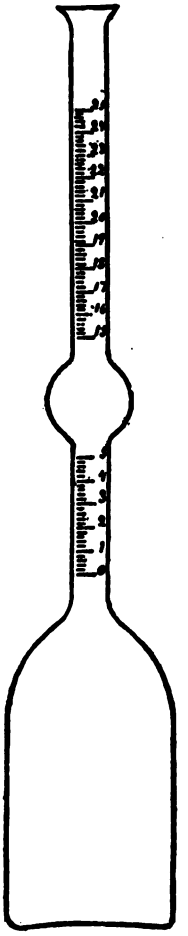


FIG. 30
BULB-NECKED
CREAM-BOTTLE

(Bull. 145, 1910, Purdue Agr. Exp. Sta.). As a result of this work, the Official Dairy Instructors' Association has adopted two forms of standard bottles for cream-testing, (1) 50 per cent., 9-gram, so called 6-inch bottle, and (2) 50 per cent., 9-gram, so-called 9-inch bottle, a detailed description of which is given on page 276.

These standard cream-bottles, have several advantages, as compared with the ordinary 18-gram bottles, among which are the following: (1) Since the graduation extends to 50 per cent., richer cream can be tested. (2) There is greater accuracy in reading the scale of graduation, since it is possible to use a neck of smaller diameter, thus increasing the distance between the smallest divisions of the scale. (3) Decreased diameter in the neck makes smaller the error introduced by the meniscus, when this is not eliminated by special treatment. (4) Direct reading of the percentage avoids the error introduced by multiplying the reading by 2, as when a 9-gram sample is tested in an 18-gram bottle. (5) The body, when large enough, permits dilution of cream with water before adding the full amount (17.5 cc.) of acid; this prevents charring of fat. (6) Some cream is saved when the tests are promptly made with each delivery in place of composite tests, the annual saving being appreciable.

CREAM-TESTING SCALES

For weighing samples of cream, a set of accurate scales is required. Different forms are illustrated in Figs. 31, 31a, 32 and 32a. Scales with agate bearings are much preferable to other forms, since the agate

bearings do not rust. Balances with parts liable to rust when kept in damp places become in time unreliable for accurate work. The scale should be kept in perfect condition and tested for accuracy from time to time, by comparing with some balance or scales of known accuracy. Scales sensitive to one-tenth and one-twentieth of a gram can be obtained.

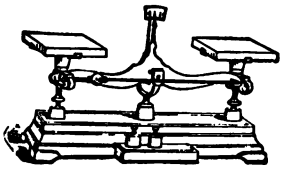
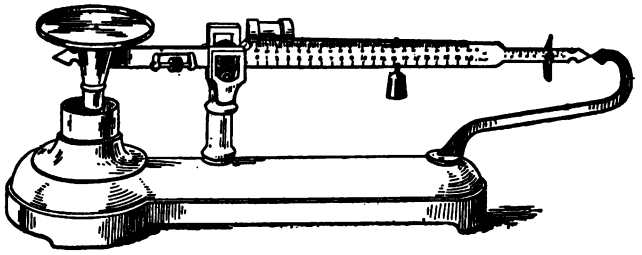


FIG. 31
CREAM-TESTING SCALES



31*a*—CREAM-TESTING SCALES

THE SAMPLING OF CREAM

When cream to be tested is fresh and easily made uniform throughout its mass by simple mixing or pouring, it is not difficult to secure a representative sample. But, with the introduction of the method of separating cream on the farm and delivery to shipping-stations or through cream-collectors, conditions are often introduced which complicate seriously the matter of obtaining representative samples. The subject will be discussed under the following divisions: (1) Farm-sepa-

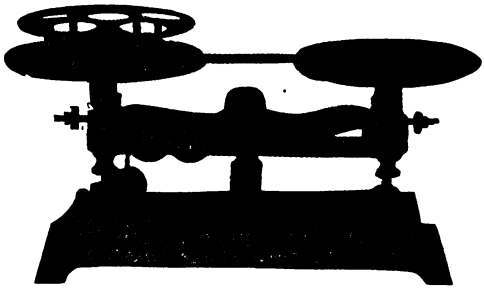


FIG. 32—CREAM-TESTING SCALES

rated cream, (2) responsible sampling agents, (3) method of sampling, (4) amount of sample.

Farm-separated cream.—When cream is directly delivered fresh at the creamery the sampling is easily

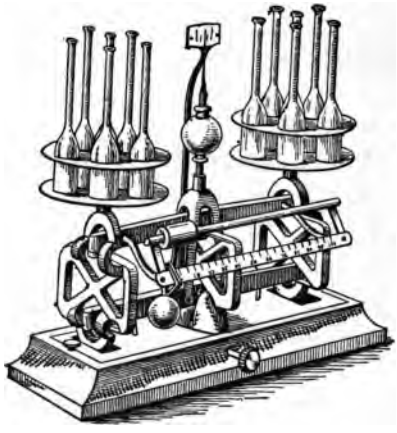


FIG. 32*a*—TORSION BALANCE FOR TWELVE BOTTLES

managed. When the cream of each producer is first taken to a shipping-station and sampled there at the time of delivery, or when the cream is collected by an agent going from farm to farm with a wagon and is sampled at the farm, difficulties are met. The trouble in obtaining samples of cream under these conditions is primarily due to lack of care of cream on the farm, which results in souring, thickening, drying, etc., conditions that cause lack of uniformity in consistency throughout the mass.

Proper conditions for producing cream that can be readily sampled may be outlined as follows: Cream, separated so as to contain about 40 per cent. of fat, is at once placed in cans in cold water and kept there, in order to prevent souring in warm weather and freezing in cold. The cream is stirred occasionally to keep the fat well distributed and to prevent drying on the surface. It should be delivered at the creamery at least three times a week in summer and twice a week in cold weather. In transporting cream that is to be sampled at the creamery or shipping-station, the cans should be full enough to prevent churning, but not too full to prevent thorough mixing of the cream in the can previous to sampling.

Responsible sampling agents.—It has been found that persons charged with taking samples, such as shipping-station agents and cream gatherers, are more often than not lacking in ability to do this work properly, either through want of adequate training or through insufficient appreciation of the importance of details. Thorough instruction, intelligence and care in details are absolutely requisite in this work.

Method of sampling.—When cream is fresh and in condition to pour easily, it is prepared for sampling by careful and complete mixing, which is accomplished by pouring cream from one can or pail to another or by agitating thoroughly from the bottom up with an efficient stirrer (Fig. 32b), or by a combination of both processes. The sample is then taken with the stirrer or with a cream-sampling tube (Fig. 5 or 6, p. 27), which must be cleaned for each sample before using; cream adhering to the outside of the sampling-tube is allowed to drip off before transferring the contents of the tube to the test sample. A common way is to stir the cream thoroughly in the can with a stirrer, then pour into the weighing-can, weigh and sample.

FIG. 32*b*
COMBINED CREAM STIRRER AND SAMPLER

When cream is not in good mechanical condition, sampling-tubes have been found unsatisfactory. In such cases, extra care is taken in mixing the cream by pouring or stirring, or both, and taking the sample with the stirrer.

Frozen cream must be thawed entirely free from ice and then well mixed before sampling. Very thick cream should be warmed until it pours easily. Partially churned cream can not be sampled with satisfactory accuracy.

Some additional details will be found helpful in the case of cream collected at the farm. The person who collects the cream is equipped with (1) a spring-

scale for weighing cream, (2) a weighing-pail for weighing each farmer's cream separately, (3) a combination stirrer and sampler properly constructed (Fig. 32b), (4) a rubber scraper for cleaning cans, (5) a case containing sample-bottles properly numbered and arranged, (6) large cans into which different lots of cream are poured after weighing and sampling, (7) a record book.

At each dairy the collector thoroughly stirs the cream with the stirrer and then pours it into the weighing-pail, weighs and samples. The inside of the weighing-pail is then carefully gone over with the rubber scraper to remove as far as possible all cream adhering. In case the patron has more cream than can be weighed in one pail, separate weighings are made and a sample is taken from each weighing, the different samples being placed in one bottle. The sample bottles are carried to the creamery and, if possible, the testing is done the same day. When composite samples are used, the contents of each sample-bottle are transferred to the corresponding composite-sample jar. When composite samples of cream are made use of, aliquot parts of cream should be taken at each sampling as in the case of milk (p. 24); however, a sampling-tube can not be used for this purpose unless the cream is in first-rate mechanical condition. The best device for taking aliquot parts of cream is a composite-test gauge, which consists of a piece of brass as long as a sample jar and which is graduated on both edges into divisions indicating the amount of cream to be taken from the lot of cream sampled. This gauge is attached to the sample jar while the

sample is being taken and cream is added to the jar until it rises to the mark representing the number of pounds of cream delivered.

Amount of sample.—It is a safe precaution to take a sample sufficient to make at least two tests; from 1 to 1½ ounces (30 to 45 cc.) will answer the purpose when each delivery is tested; less from each delivery will answer in case of composite sample.

METHOD OF KEEPING CREAM SAMPLES

In general, the same precautions are observed in keeping samples of cream as in the case of milk (p. 20), whether single or composite samples. Samples that are not tested soon after reaching the creamery should be treated with a small amount of preservative (p. 28). With thick cream, special effort should be made to cause the preservative, especially bichromate, to dissolve completely and be distributed through the sample. This may be done by agitating the cream carefully by a gentle, rotary motion, warming slightly if necessary. With composite samples, the contents of the bottle are shaken after each addition of cream until there is a complete, uniform mixture. It may be said, in general, that lack of proper care of cream samples introduces even greater errors in the results of the test than is the case with samples of milk.

AGE OF SAMPLES WHEN TESTED

In the best-managed creameries, cream is delivered two to three times a week and each individual shipment is sampled and tested on the day of delivery or within 24 hours. The method of using only composite samples in cream-testing is gradually being

displaced; it has been strongly condemned by many on the basis of actual, comparative results. While it possesses the single advantage of reducing the cost and work of testing, the disadvantages connected with it entirely overcome this one advantage. An added advantage of testing each delivery of cream promptly, is that the use of a preservative is avoided and any unused portion of the cream sample left can be poured back into the cream-vat, thus avoiding appreciable waste when large numbers of samples are considered.

PREPARATION OF SAMPLES FOR TEST

If the cream is fresh and not too thick, the only preparation required to make the sample uniform, previous to weighing sample, is to give the bottle a rotary motion or to pour the cream carefully.

Very thick, heavy cream, often found in case of samples kept very cold, is warmed to a temperature not above 85° or 90° F., then poured carefully and weighed quickly.

As recommended by Hills (Bulletin 100, Vermont Exp. Sta.), lumpy cream is passed through a small sieve (Fig. 33), such as is commonly used in kitchens. Any remaining lumps found in the sieve are rubbed through the meshes by the fingers, after which the cream is thoroughly mixed by pouring from one cup to another. The sample is then quickly taken for testing.

In the case of a cream sample in which the fat is completely separated, or churned, or is changed into a tough, leathery consistency (conditions often found in carelessly-stored composite samples), it is heated to a temperature of 105° to 110° F. to melt the fat,

after which it is vigorously and continuously shaken until cooled to 60° F. or lower, and then the sample is taken and weighed as quickly as possible. Agitation during the process of cooling is essential to keep the melted fat from separating so rapidly as to prevent obtaining a uniform mixture.

WHY USE OF PIPETTE IS INACCURATE FOR CREAM

The use of a pipette for measuring cream samples is inaccurate for the following reasons: (1) More fat adheres to the inside of a pipette than in case of milk, the error increasing with the thickness of cream. (2) The weight of cream decreases as the per cent. of fat in cream increases, since milk-fat is lighter than the other constituents of cream. The scale of the test-bottle is based on the use of 18 grams of material, but the amount of cream that occupies the volume filled by 18 grams of milk (17.5 cc.) is found to be more or less below 18 grams according to the increased percentage of fat in the cream, running even below 17 grams in very rich cream. (3) Separator cream is more or less filled with bubbles of air, and ripened cream contains gases produced by fermentation. These decrease the weight of a given volume of cream.

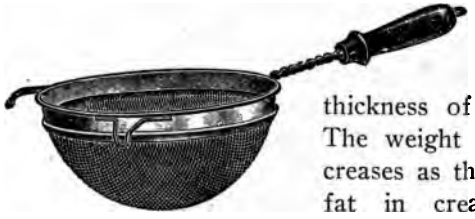


FIG. 33
CREAM-SAMPLING SIEVE

For the preceding reasons, the result of trying to

measure by pipette a sample of cream to be used for testing its fat content is that less cream will be used than should be, and therefore the results will be too low. Any system of volumetric measurement proposed is open to some uncertainty and inaccuracy. The use of a pipette in testing cream is justifiable only for work that is not expected to be strictly accurate.

If one uses a pipette in measuring cream for testing, accuracy of results are generally improved by measuring 18 cc. of cream and also rinsing the pipette into the test-bottle with a small amount of water. Pipettes are obtained which have an 18 cc. mark as well as a 17.6 cc.

In several States, laws have been passed making it illegal to test cream in any other way than by weighing the sample to be tested, when the fat is used as a basis of paying for cream.

WEIGHING SAMPLE OF CREAM

Using 18 grams.—The operation of weighing cream is simple. One places the empty test-bottle on one pan of the scales and balances it by a slide-weight or some form of counterpoise. One then places an 18-gram weight on the other pan, after which the pipette is filled with cream somewhat above the 17.6 cc. mark, and this is run into the bottle, the last portion being run in more slowly until the two scale-pans just counterbalance each other. A little practice enables one to weigh the exact amount rapidly. In case the amount of cream taken in the pipette is not enough, agitate the sample, draw a little into the pipette and run this slowly into the bottle until it counter-bal-

ances the weight. In case too much cream is run into the bottle, the surplus can easily be withdrawn by the pipette. No cream must be allowed to get on the outside of the bottle or on the scale-pan while the weighing is done.

Using less than 18 grams.—As we have already noticed, special bottles are made which have the graduated scale based upon the use of 9-gram samples, and the results are then read directly from the neck without any kind of correction. When, however, we use 9-grams of cream in a bottle made for an 18-gram charge, as may be done in case of very rich cream, the reading of the fat-column is multiplied by 2; any error in the test is, therefore, doubled in the final result. A somewhat inconvenient method, which is little used, is to weigh an 18-gram sample and divide it between two cream bottles, in which case water is added to each bottle in amounts sufficient to bring the mixture to about 18 cc. in volume. The results of the test in the two bottles are added.

It will be found more convenient with a little practice to weigh exactly 9 or 18 grams than to run in an approximate amount and weigh that accurately.

In case one uses in 18-gram bottles any amount less than 18 grams for a sample, it is necessary to correct as follows the per cent. of fat read: Divide 18 by the number of grams of cream used and multiply the result by the per cent. of fat read in the test. For example, one uses 13.5 grams of cream and the result reads 15.6 per cent. of fat. Divide 18 by 13.5 which gives 1.33, and multiply this by 15.6, which equals 20.8 per cent., the true percentage of fat in the sample.

VARIATIONS IN DETAILS OF TEST

In carrying out the details of the Babcock test with cream, some of the details require modification in comparison with the test as applied to milk. The points to which we will call special attention in this connection are the following: (1) Amount of acid used, (2) addition of water, and (3) control of meniscus.

Amount of acid.—The amount of sulphuric acid (p. 43) that is needed to give good results varies somewhat (1) with the percentage of fat in the cream, or, stated in another way, with the percentage of solids not fat, and (2) with the temperature of cream and acid. In illustration of the first point, Hunziker gives the following results at about 70° F.:

Per cent of fat in Cream.	Cream Used for test.	Amount of acid used. Largest	Smallest.
50	18 grams	13 cc.	8 cc.
50	9 "	7.5 cc.	4.5 cc.
28	18 "	15 cc.	11 cc.
28	9 "	8 cc.	5 cc.

It is seen that for any one sample the amount of acid used can be varied considerably without affecting the results of the test. The safest guide to follow in deciding how much acid to use is the color of the cream and acid after they are mixed. The mixture of cream and acid is generally lighter in color at first than in case of milk, because the sugar and casein are less. Acid can be added until the mixture, after being agitated, has a brownish color, similar to that produced by mixing coffee and cream. It is usually well to let the bottle stand after mixing the cream and acid until the mixture turns dark, before whirling. Less acid can

be used at higher temperatures and more at lower (p. 43).

It is the custom of many, when using less than 18 grams of cream, to add enough water to make the volume about 18 cc., mixing well before adding the acid. This calls for a larger amount of acid, of course, than when no water is added to the cream, because the water weakens the acid.

Addition of water after whirling.—A cleaner column of fat is usually obtained by adding water twice after the first whirling, as in the case of testing milk (p. 64). With a single addition of water, the lower line of the fat-column is cloudy-looking and uneven and indistinct, while the liquid below is milky. This condition may often be remedied by placing the bottles in water at 130° to 140° F. for 15 or 20 minutes before a final whirling, or, if this fails, the fat can be solidified by placing the bottles in cold water after the last whirling and then heated to 130° or 140° F. before reading.

Control of meniscus in reading fat-column.—There has been much inaccuracy introduced into the testing of cream by the variable factor of the meniscus in the fat-column; the details of the trouble need not be discussed here. The only reliable method of removing this source of inaccuracy is to get rid of the meniscus, changing the upper curved surface of the fat-column into a flat surface. This can be accomplished by the use of several agents, among which are (1) glymol, (2) amyl alcohol and (3) alcohol saturated with fat. When any one of these solutions is placed on top of the fat-column, it keeps separated from the fat but re-

moves the meniscus, leaving a straight surface as a distinct boundary between the two liquids. This makes it easily possible to read the top of the fat-column with a satisfactory degree of accuracy. The operation of using any of these solutions is simple; a small amount is dropped into the opening of neck of the bottle so as to rest upon the column of fat.

(1) *Glymol* is commonly known in commerce as white mineral oil, (also sold under other names as alboline, blancoline, glycoline, etc.), and is used as a lubricant in typewriters, sewing-machines, etc. It costs about 75 cents a gallon. It is a product formed in the distillation of petroleum. It is a clear, colorless, odorless and non-volatile oil. It can be obtained at any drug-store. The glymol can be added to the test-bottle just before the results are read. The line of division between glymol and the top of the fat-column can be made sharper by coloring the glymol. One ounce of crushed alkanet root (obtainable at drug-stores) is wrapped in a small piece of cheese-cloth, placed in one quart of glymol, and left for a day or two. The glymol takes on a bright cherry color. Its use has been thoroughly investigated by Hunziker. It may be added that Standard Hand-Separator Oil, put up by the Standard Oil Company, gives as good results as glymol.

(2) *Amyl alcohol,* colored red with fuchsin, has been proposed by Eckles. It is less useful than glymol, since amyl alcohol may give a reading somewhat low on account of dissolving a small amount of fat.

(3) *Alcohol saturated with fat* has been used at the Wisconsin Station. It is made by shaking a tea-

spoonful of butter with about 6 ounces of denatured alcohol or of wood alcohol. The mixture is placed in warm water and slightly warmed and then shaken until the butter ceases to dissolve. This solution can be slightly colored, if desired.

CHAPTER VI

Methods of Testing Skim-Milk, Buttermilk, Whey, Ice-cream, Condensed Milk and Powdered Milk

Dairy products such as ice-cream, condensed milk and powdered milk can be tested for fat by the Babcock method, and also by-products, such as skim-milk, buttermilk and whey; but in general, some special modifications are necessary.

METHOD OF TESTING SKIM-MILK, WHEY, ETC.

In testing materials containing only .2 or .3 per cent. of fat, two difficulties are experienced: (1) In the ordinary test-bottle, the reading of so small amounts of fat can not be easily done with accuracy. (2) Some fat is necessarily left in the mixture of acid and milk-serum, which may constitute an important factor when the total fat content is small.

Special forms of test-bottles used in testing whey, etc.—To enable one to make readings of small amounts of fat with increased accuracy, special forms of double-necked test-bottles have been devised, which are so graduated as to enable readings to be made as low as .01 per cent. (Figs. 34 and 34a). In using these bottles, the milk and acid are delivered into the larger neck, the fat being driven up into the small neck by the hot water added toward the end of the test.

Enough water is added to bring the fat-column into the middle of the small neck. In mixing milk and acid and in running in hot water, care must be taken to prevent any liquid but fat going into the small neck or fine measuring-tube. The stoppers in the bottles

FIG. 34 FIG. 34*a*

BOTTLES FOR TESTING SKIM-MILK

are used to adjust the fat-column for reading. These double-necked bottles should be placed in the tester in such a way that the filling-tube is toward the center, thus avoiding the danger of having any fat caught between this tube and the side of the bottle when resuming the upright position after whirling.

Separating fat from mixture in bottle.—Attention has previously (p. 68) been called to the difficulty experienced in separating all the fat from the mixture

of acid and milk-serum. Under ordinary conditions of working, materials low in fat, like skim-milk, may fail to give up to the fat-column .05 or even .1 per cent. of fat. Some double the reading of fat when it is below .1 per cent. in order to make allowance for the unseparated fat. The fat may be separated from the rest of the liquid more completely by proceeding as follows: Use 20 cc. of sulphuric acid, whirl the bottles at full speed 3 to 5 minutes longer than usual and read the fat when at a temperature of 130° to 140° F. Steam-turbine testers, which keep the bottles hot, give best results. Any test of these by-products showing less than .05 per cent. of fat is open to the suspicion of being defective.

Skim-milk and buttermilk are treated alike. In working with whey, it is noticeable that after adding acid the mixture turns dark very slowly, due to the presence of less sugar and to the absence of casein. Less than the usual amount of acid is sufficient for whey, 8 or 10 cc. frequently being sufficient.

METHOD OF TESTING ICE-CREAM

In applying the Babcock test to the determination of fat in ice-cream, the regular method of procedure must be modified in such a way as to prevent undue charring of the sugar. Of the methods in use, we will describe three, one by White (Pennsylvania State College), one by Holm (Chicago Dep't of Health), and the other by Ross (Cornell Univ. Coll. of Agr.).

Whatever method is used, the same process of taking and preparing samples applies to all. A special sampling-tube or a butter-trier can be used in drawing

samples, several plugs being drawn and placed in the sample jar. The jar containing the material is then placed in water heated to 80° F. and agitated with a rotary motion until the ice-cream is melted. The melted cream is then poured through a cream-sampling sieve (Fig. 33, p. 86) into a cup or beaker, any lumps being rubbed through with the fingers. The sample is then thoroughly mixed by pouring several times from one beaker to another and the weighing is made at once as in the case of cream (p. 87).

The method of testing described by White is essentially as follows: A 6-gram sample is weighed into an ordinary milk-testing bottle. With a 6-gram sample, one adds 4 cc. of sulphuric acid (sp. gr. 1.83) and carefully mixes the cream and acid; after about two minutes, one adds 4 cc. more of acid and again carefully mixes. The mixture should be of a light-brown color; if it should be black, the test should be begun again, another sample being weighed and less acid used. The bottle is at once placed in the steam centrifuge and whirled as rapidly as possible for three minutes. The test is then completed by addition of hot water and repeated whirling. It is best to add the hot water in two portions, whirling three minutes after the first addition of water and two minutes after the second addition. The percentage of fat shown is multiplied by three.

In Holm's method, a mixture of equal parts of hydrochloric and 80 per cent. acetic acid is substituted for sulphuric acid. A sample of 9 grams is weighed into a milk-testing bottle, and 30 cc. of the acid mixture added. The bottle is then placed in hot water and

kept there until the contents are well darkened but not charred. The test is completed in the usual manner. The fat-reading is multiplied by 2.

The method of Ross is as follows: Mix thoroughly equal weights of melted ice-cream and water at 100° F. Weigh 9 grams of the diluted cream (containing 4.5 grams of ice-cream) into a cream-testing bottle, preferably a 9-gram bottle with a body of the same size as that of an 18-gram bottle, though a regular 18-gram bottle can be used. To the contents of the bottle add 17.5 cc. of glacial acetic acid and agitate 2 or 3 minutes. Then add 15 cc. of sulphuric acid (sp. gr. 1.82-1.83) and agitate about a minute. Complete the test in the usual way. Since the amount of ice-cream used is 4.5 grams, the result is multiplied by 2 if a 9-gram bottle is used and by 4 for an 18-gram bottle.

METHOD OF TESTING UNSWEETENED CONDENSED MILK

The most effective adaptation of the Babcock method to the determination of fat in unsweetened condensed milk is that worked out by Hunziker (Bull. 134, Ind. Exp. Sta.). Dilute the sample of milk with an equal weight of water and weigh 9 grams of this diluted milk into a Babcock milk-testing bottle (graduated to 10 per cent.) and add one-half of a pipetteful of water (about 9 cc.). Then add 17.5 cc. of sulphuric acid and agitate until the curd dissolves completely and whirl, as in testing milk, for 5 minutes. Then fill bottle to the zero mark with hot dilute sulphuric acid, made by mixing equal parts of sulphuric acid and water, adding the acid to the water (p. 44). (Where

only one or two tests are made, one pipetteful of water and one acid measure full of acid answer the purpose.) The bottles are then whirled for 2 minutes, filled with hot water to about the 8 per cent. mark, and whirled again for 1 minute; the reading is made at 140° F. from the bottom of the lower meniscus to the extreme top of the upper meniscus. The result is multiplied by 4.

For accurate results, weighing the sample is indispensable. Approximate results can be obtained by diluting a measured amount of condensed milk with three volumes of water and agitating until the mixture is uniform. A 17.6 cc. sample of this is taken and the process above described followed.

For condensed milk containing added sugar,— Many brands of condensed milk contain added cane sugar, which in testing is so blackened by the acid as to make the results unreliable. This trouble can be overcome by special treatment devised by Farrington. Dissolve 40 grams of condensed milk in enough water to make 100 cc. of solution. With a 17.6 cc. pipette, measure the same amount as for a milk test into a milk-testing bottle. Add about 3 cc. of the sulphuric acid used in the test and mix the acid and milk by shaking vigorously. The acid is added to coagulate the curd and enclose the fat, allowing the sugar to separate in the surrounding liquid. The curd is compacted into a lump by whirling the test-bottles in a steam-turbine tester at high speed and at a temperature of 200° F. After this whirling, the bottles are taken from the tester and the liquid portion, containing much of the sugar, is carefully poured

from the neck without breaking the lump of curd. Then an addition of 10 cc. of water is made to the test-bottles, the curd is shaken up to wash out more sugar, and again 3 cc. of sulphuric acid added. The bottles are again whirled and the liquid portion decanted. Then the test is completed by adding 10 cc. of water, 17.5 cc. of sulphuric acid, and proceeding as usual. Correct the fat-reading by multiplying by 18 and dividing by 7.

METHOD OF TESTING DRIED MILK, MILK POWDER, ETC.

Successful means of drying milk have recently been devised, and products are appearing on the market in the form of dried skim-milk and whole milk. These materials are in the form of fine flaky or powdery substances. Owing to the great advantages of handling milk in such forms, these products are destined to find extensive use, and the desirability of testing them is obvious.

The Babcock test, when applied to these materials, gives results much below the truth. Various attempts have been made to adopt the Babcock test to these products, the most satisfactory of which is that of Redmond (Journal of Industrial and Engineering Chemistry, Vol. 4 (1907), page 544). Weigh 2.5 grams of milk powder and transfer it to an ordinary 10 per cent. Babcock milk-bottle. A small glass funnel is useful in transferring the powder. Add 31 cc. of dilute sulphuric acid (made by pouring 395 cc. of concentrated acid into 605 cc. of water) and place the bottle upright in a dish of gently boiling water. Shake

frequently and keep in the boiling water until all the powder is dissolved and the solution is dark brown in color, which usually requires 7 to 10 minutes. After removing the bottle from the water add 12 cc. of strong sulphuric acid (sp. gr. 1.82 to 1.83) and mix thoroughly, by agitation with a rotary motion taking care to keep the solution from getting into the neck of the bottle. Place the bottle in a centrifuge and whirl 4 or 5 minutes. Add hot water until the solution reaches the lower end of the neck, whirl again for 1 minute and then add hot water until the fat rises. Finally whirl again 1 minute. Read fat column at 130° to 140° F. Readings should be made to 0.05 per cent. on the graduated scale. The reading is multiplied by 7.2 to obtain the percentage of fat in the material tested.

CHAPTER VII

Methods of Testing Butter and Cheese for Fat

The Babcock test has not been adapted to determine the amount of fat in butter as accurately as in case of other milk products. A mass of butter is so variable in composition, owing to the uneven distribution of water, that it is difficult to obtain a representative sample when only a small amount is used. Other specific conditions which make the application of the Babcock method less satisfactory than in case of other dairy products we need not consider in detail. Approximate results can be obtained by observing certain precautions.

PREPARATION OF SAMPLE OF BUTTER

Whatever constituent of butter is determined and whatever method is used, extreme care must be exercised in taking and preparing samples for testing.

With a butter-trier draw from different parts of the package or mass several portions of butter aggregating 4 to 8 ounces. Place these portions in a fruit-jar or composite-sample bottle, melt completely by placing the closed jar in water at 100° to 110° F.; then remove from the warm water and shake vigorously for one or two minutes, after which moderate agitation is continued until the butter solidifies. The cooling may be hastened by holding the jar under a stream of cold

water, continuing to shake the bottle vigorously until the butter hardens.

Another method is to place the jar containing the butter in water at 100° to 110° F., leaving it only until the butter just begins to melt. With a long knife or spoon mix the melted and unmelted portions as completely as possible. Then replace the jar in the warm water until melting begins again, remove from the water and stir thoroughly as before. The process of softening and mixing is repeated until the sample contains no lumps and the consistency of the mass is about like that of thick cream. The jar is then placed in cold water and the sample vigorously stirred while the butter is hardening. Care must be taken to keep the butter scraped off the sides of the jar where it begins to harden more quickly than toward the center. When the sample has cooled to a consistency about like that of ordinary butter, the stirring is discontinued. The jar is then kept closed except when removing a sample for weighing.

MODIFIED BABCOCK TEST FOR BUTTER

For strictly accurate results gravimetric methods must be used. Where only approximate correctness is desired, some modification of the Babcock test will answer.

On a cream-scale place a bottle of the kind shown in Fig. 35 or one of similar construction. After balancing the bottle, take small pieces of butter on the point of a knife from different parts of the sample in the jar, prepared as described in the previous section, and place them in the funnel-shaped tube of the bottle

until the test sample weighs 9 grams. The bottle is then placed in hot water until the butter melts and runs into the body of the test-bottle. The fat adhering to the inside walls of the funnel is washed down into the bottle with 8.8 cc. (one-half pipetteful) of hot water, and the same amount (8.8 cc.) of sulphuric acid is added. After the contents are thoroughly mixed, the bottle is placed in a centrifuge and whirled for about 5 minutes. To read the result, the funnel-shaped tube is filled with hot water, which raises the fat-column into the graduated neck. By gently pressing down or gently drawing up the rubber cork at the top of the graduated neck, the fat-column may be moved down or up in the graduated neck so as to bring the lower end of the column level with the zero mark, which is indicated by a ring below the bulb. The percentage of fat is read directly. Before making the final reading, let the bottle stand for 10 minutes in water at 120° F. With careful attention to all details, results of approximate accuracy can be obtained.

FIG. 35
BOTTLE FOR USE IN TESTING BUTTER

SHAW TEST FOR FAT IN BUTTER

This method was devised by R. H. Shaw, chemist in the Dairy Division of the Bureau of Animal Industry, U. S. Department of Agriculture (Circular 202). It is a strictly gravimetric method, not only the sample of butter being weighed but also the amount of

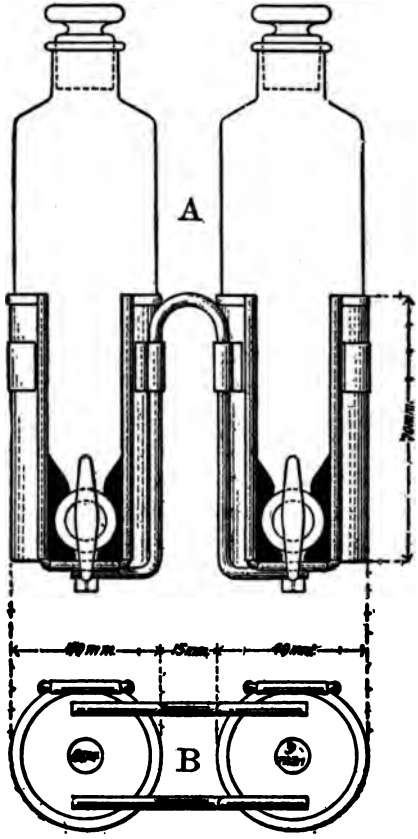


FIG. 36—DOUBLE SOCKET WITH FUNNELS IN POSITION

B, view of socket from below. Care must be taken that the capillary stem of the funnel does not project far enough through the hole at the bottom of the socket to strike against the side of the centrifuge when whirling. A rubber gasketing should be fitted to the bottom of the socket.

purified fat that is obtained. In brief outline the method is as follows: The salt and part of the curd are first removed from the butter with hot water; the remaining curd is dissolved in dilute sulphuric acid, the acid solution is removed from the fat and the latter weighed.

Apparatus required: (1) Babcock centrifuge with special sockets providing openings in side (Fig. 36). (2) A special separatory funnel (Fig. 36a), (3) A balance sensitive to 0.01 gram (a torsion balance in good condition, such as is used in moisture tests, will answer). (4) An accurate set of metric weights. (5) A 10 cc. graduated glass cylinder. (6) A 100 cc. glass beaker.

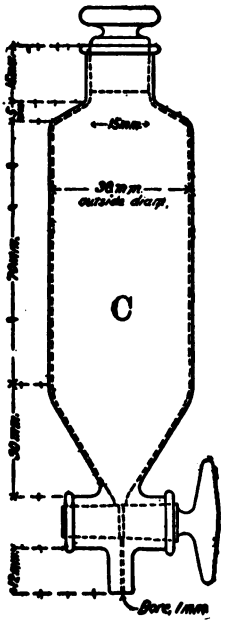


FIG. 36a
SEPARATORY FUNNEL WITH CAPILLARY STEM

Operation of test.—The operations required to perform the details of the test are as follows: (1) Weighing sample, (2) transferring weighed sample to separatory funnel, (3) whirling, (4) removal of water, (5) dissolving of curd, (6) separation of fat from acid solution, (7) determination of percentage of fat, (8) cleaning funnels.

(1) *Weighing sample.*—Counterpoise the small beaker on the balance and carefully weigh 20 grams from the sample prepared as already described (p. 101).

(2) *Transferring weighed sample to funnel.*—Previous to use, each separatory funnel, clean and dry, must be weighed accurately and a record kept of the weight of each. In order to transfer the butter from the beaker to the funnel, the butter in the beaker is melted by warming either by addition of a small amount of boiling water or by putting in a warm place. The melted sample should then be poured *without loss* into the funnel, which must be held upright. The sides of the beaker are rinsed with a *fine* stream of hot water, using not more than a teaspoonful each time, and the rinsings poured into the funnel; this treatment is repeated until the funnel is full to within one-quarter of an inch of the shoulder.

(3) *Whirling.*—The separatory funnel is then inserted in the special socket of the centrifugal, allowing the stem to project through the hole in the bottom, and the handle of the stop-cock through the open side (the socket always being placed in the centrifuge with the open side facing in the direction in which the wheel revolves, in order to prevent the stop-cock being thrown out and broken). The funnel is whirled one minute at the speed used in testing milk (p. 41). The centrifuge must be kept warm.

(4) *Removal of water.*—The funnel is taken from the centrifuge and the water is allowed to flow through the stop-cock. Most of the salt and some of the curd are taken out by the water. The rest of the curd and all of the fat remain in the funnel. (Care must be taken to keep the stop-cock always under control, so that it can be closed at the right instant and thus prevent fat running out and consequent loss of

the test. Control of the stop-cock can be maintained by giving it frequent and slight movements while the water or acid is running through it.)

(5) *Dissolving the curd.*—Into the beaker pour 9 cc. of cold water; then add 11 cc. of sulphuric acid (sp. gr. 1.82 to 1.83) and mix by gentle shaking. This mixture is added at once, before cooling, to the contents of the funnel and then this is given a rotary motion, with the hand grasping the neck, until the curd is completely dissolved. It is then whirled in the centrifuge one minute, after which the acid solution is drawn off until the layer of fat is within a quarter of an inch of the stop-cock. The operation of treating with a mixture of acid and water, whirling, etc., is repeated.

(6) *Separation of fat.*—The fat now appears as a clear, transparent layer, free from curd, and the solution below it is practically colorless. To separate these two, draw off the latter until the fat nearly reaches the stop-cock, and whirl again for one minute. Then draw off the solution again until the fat just reaches the end of the capillary stem, care being taken to keep the working of the stop-cock under complete control.

(7) *Determination of percentage of fat.*—The outside of the separatory funnel is completely dried by wiping with a dry cloth and the funnel is then weighed. The weight of the funnel and fat, minus the weight of the empty funnel, gives the weight of fat in the 20-gram sample. This result, multiplied by 5 gives the percentage of fat in the butter tested.

(8) *Cleaning funnels.*—After completing each test,

the separatory funnels should be thoroughly cleaned. This is easily done with hot water together with soap or cleaning-powder, after which the funnels are well rinsed with clean water and allowed to drain.

PREPARATION OF SAMPLE OF CHEESE

Since different portions of the same cheese vary in composition, special means must be used to get a representative sample. The sample for testing is prepared as follows: When a cheese can be cut, a narrow, wedge-shaped segment is taken, reaching from the outer edge to the center. This is cut into strips and passed through a meat-grinding machine two or three times. This mass is carefully mixed, and from this a sample is weighed.

When cheese can not be cut, samples are obtained by a cheese-trier. If possible, three plugs should be drawn, one at the center, one about an inch from the outer edge, and one at a point half way between the two. If only one plug can be drawn, this should be taken at a point about half way between the margin and center. The plugs should be taken perpendicular to the end surface of the cheese and should reach either entirely through the cheese or just half way. The plugs should be made fine by grinding or cutting and carefully mixed before weighing samples. In preparing samples, they should not be exposed to the air longer than necessary, since loss of moisture should be prevented as much as possible before weighing.

BABCOCK TEST FOR CHEESE

From the sample prepared in the manner described in the preceding section, weigh a 9-gram sample into a cream-testing bottle or a 4.5-gram sample into an ordinary milk-testing bottle.

In the case of well-ripened, softened cheeses of the hard varieties and in the case of all soft varieties, the following method is appplicable: Add about 15 cc. of hot water to the test-bottle and agitate until the cheese is disintegrated; this can be hastened by adding a few cubic centimeters of sulphuric acid and keeping the bottle in warm water. When no more lumps are seen in the mixture, add 17.5 cc. of sulphuric acid. The test is then completed in the usual way, making correction in reading when necessary (p. 88).

In cheese-curd and unripened hard cheese, the foregoing method requires too much time to dissolve the curd, and for such cases Sammis finds the following method to work rapidly and satisfactorily: To the weighed 9-gram sample of cheese in a cream-testing bottle add 10 cc. of water at 125° to 135° F. and then at once add sulphuric acid at first in small portions of about 1 cc. each, agitating vigorously after each addition. The addition of acid is continued until 17.6 cc. has been used. Loss by spurting is avoided by adding the acid in small portions at first. By the time all the acid has been added, a final vigorous agitation reduces the larger lumps to fine grains which quickly dissolve in the strong acid without the necessity of additional heating.

CHAPTER VIII

Methods of Testing Butter for Water

Numerous methods designed for the determination of water, adapted for creamery use, have been called into existence by the enactment of laws controlling the percentage of water in butter. All methods are based upon the same general process; the water is evaporated from a weighed portion of butter and the amount removed is then ascertained usually by weighing the dried residue, but in some cases by distilling and measuring the evaporated water. The apparatus and materials required for any of the methods can be obtained at dairy-supply houses. The various methods in use differ in the details and, before describing any of them we will notice certain points of resemblance and difference, such as relate to (1) preparation of sample, (2) weighing of sample and amount used, (3) evaporation of water, (4) ascertaining the amount of water evaporated, and (5) calculation of percentage of water in butter.

PREPARATION OF SAMPLE

The sample of butter must always be taken and prepared with special care (p. 101), whatever method of determining water is used. Unless the sample is truly representative, the results of testing are useless or worse. When only approximate results are desired, it may answer the purpose to take samples directly

from a package of butter without special preparation provided the total amount used for evaporation is as large as 50 grams.

WEIGHING SAMPLE AND AMOUNT USED

Weighing should be made only on an accurate scale or balance sensitive to 0.025 gram. The vessel in which the butter is weighed must be clean and dry before use. If samples as large as 50 grams are used, scales sensitive to 0.1 gram answer.

The amount of sample used may, for convenience, be 10 grams or some multiple of this. The larger the amount of samples used, the greater must be the care in making evaporation complete.

For careful work in determining water in butter, weighing should be done in a suitable room especially fitted for the purpose; this room should be kept free from dampness and dust. The scale or balance should be protected from dampness, dust and, especially when weighing, from drafts of air, which can easily be done by placing it in a tightly-made box or case of convenient size provided with a door in front, which is kept closed when the scale is not being used. This box can be set on a firm table or fastened securely to the wall at a convenient height, care being taken to have the scale exactly level. Additional protection from dampness is afforded by placing in this box near the scale a teacup quarter full of strong sulphuric acid or dry, fused calcium chloride; these substances absorb atmospheric moisture and must be replaced from time to time with fresh material.

EVAPORATION OF WATER

In the case of all methods, the vessel containing the weighed sample of butter is subjected to heat to evaporate the water. The means of applying heat vary; in some cases, the vessel is heated directly over an alcohol or gas flame, or there may be interposed a thin sheet of asbestos or iron plate; in other methods, the dish is placed in some form of drying-oven, heated by steam under pressure.

In the process of evaporation, certain precautions must be observed, especially in reference to (1) length of time of heating, and (2) loss by sputtering.

Length of time of heating.—This depends mainly upon the size of the sample, the degree of temperature, and the diameter of the dish in which the sample is heated.

The objection to heating at high temperature longer than is necessary to evaporate the water completely is that other material is in danger of being driven off from the butter, the consequence being that the results are too high. How can we tell when the water is completely removed? This is, for the most part, a matter of experience. Generally, the appearance and behavior of the dried residue are depended upon to indicate when evaporation is complete. When butter is heated in an open dish, a foamy, snow-white covering collects over the surface as soon as the butter becomes quite hot; this white covering changes to a dirty-brown color, and the crackling noise due to the escape of water-vapor ceases, after the heating has been continued some time, and then a slightly pungent odor is usually noticeable. These conditions indicate

that the water has been completely evaporated, the dark color and pungent odor showing that other butter constituents are beginning to undergo decomposition; heating should then cease at once. So long as any snow-white portions remain, the evaporation is not complete.

The escape of water-vapor is facilitated by shaking the dish with a rotary motion from time to time during the evaporation, thus breaking up the surface covering, which tends to prevent the escape of water-vapor. Experience enables one quickly to detect the point at which heating should be stopped.

Another method of telling when evaporation is complete is to hold the face of a mirror over the heated sample after foaming ceases; the process is complete when no moisture gathers on the mirror. Care must be taken to keep the mirror from becoming too warm to condense water-vapor. This may be done by using two mirrors alternately, allowing one to cool while the other is being used.

In the case of samples heated in an oven, it is well to make some experiments. Remove the evaporating dish, when the darkening of the residue appears, cool and weigh, after which replace the dish in the oven and heat again for 10 or 15 minutes; if the water was removed by the first heating, the sample will weigh the same as before, while decrease in weight after the second heating will show that the first heating was insufficient to complete the evaporation. A few trials of this kind will enable one to tell very closely how long it will be necessary to heat for complete evapora-

tion in the case of samples of a given weight and at a definite temperature.

Loss by sputtering.—When butter is heated very rapidly, the sudden escape of water-vapor is liable to cause sputtering, throwing some of the material out of the evaporating-dish and thus causing too high results. This is apt to happen when the dish is heated over a high gas flame. The use of an alcohol lamp or the interposition of a piece of thin asbestos or iron plate over the flame obviates this difficulty. Sputtering may also occur in a high-pressure oven if the temperature is too high during the first part of the process.

ASCERTAINING THE AMOUNT OF WATER EVAPORATED

In most methods the amount of water evaporated is found by subtracting the weight of the cooled dish and contents after heating from the weight of the dish and contents before heating; the weight lost during heating represents the amount of water in the butter. The cooling and weighing should be done in a room where the air is fairly dry. In some methods, the evaporated water is condensed in a graduated tube and measured directly.

CALCULATION OF PERCENTAGE OF WATER IN BUTTER

In the case of those methods which condense the evaporated water, the percentage of water in the butter tested is read directly from the graduated tube. When the water is evaporated into the air and its amount determined by the weight lost, the percentage is calculated as follows: Divide the loss of weight by the

weight of the sample used and multiply the result by 100. For example, a 10-gram sample after evaporation of water weighs 9 grams; the difference (1 gram) is the amount of water, which is 10 per cent. of the butter sample tested. The arithmetical operation is indicated as follows:

1 (weight lost in grams) ÷ 10 (amount of sample in grams) × 100 = 10 (the per cent. of water in the butter). In case of a 50-gram sample, which loses 7 grams of water, we have the following: 7 ÷ 50 × 100 = 14 (the per cent. of water in butter).

CORNELL TEST FOR WATER IN BUTTER

This was devised by Ross at the Cornell University experiment station. The apparatus required includes (1) an alcohol lamp; (2) a cast aluminum cup or beaker for holding and heating sample. (A convenient size for this and similar tests is about 3 inches high and 2 inches in diameter); (3) an iron stand; (4) a thin sheet of asbestos; (5) a hand-clamp for lifting the cup. While any balance or scale of sufficient delicacy can be used, Ross recommends as most convenient a special form (Fig. 31a, p. 79) which enables one to calculate the results on the arm of the scale; this scale is well adapted for cream-testing also. The distinctive feature of this method is mainly the use of asbestos between the dish and flame.

The operation is carried out as follows: The sample of butter (20 grams) properly prepared (p. 101) is weighed into the clean, dry aluminum cup, the weight of which has already been found. The alcohol lamp is

placed under the asbestos sheet, which rests on the iron stand. The cup with the weighed sample in it is placed on the asbestos with the lifter and allowed to remain until the foamy, snow-white covering that is soon formed changes to a dirty-brown color, which is usually accompanied by a slightly pungent odor. The dish is at once removed from the asbestos, allowed to cool to room temperature and weighed. The percentage of water in the butter tested is calculated as already described (p. 115).

While the sample is being heated, it should be shaken from time to time with a rotary motion in order to break up the surface covering and facilitate the escape of the water-vapor. So long as snow-white portions remain, the evaporation is not complete.

When the special form of scale that is recommended is used, a sample weighing 20.2 grams is taken, which permits direct reading on the scale-arm of the percentage of water in butter.

The Cornell method possesses the advantages of simplicity, ease of operation and reasonable accuracy; the apparatus is inexpensive and durable.

The Ames method, devised by McKay and Bower at the Iowa experiment station, differs from the Cornell method mainly in that the dish containing the sample of butter is heated over melted paraffin at a temperature of about 175° F. This permits good control of temperature and yields good results. Some find the use of a paraffin bath objectionable on account of possible danger of catching fire. Paraffin that has been repeatedly heated is apt to undergo some decomposition and give off an unpleasant odor.

WISCONSIN MOISTURE TESTS

At the Wisconsin Experiment Station, two forms of heating apparatus have been devised. In the Benkendorf test (Fig. 37) the special device consists of a small oven-like casting with an open space to receive the evaporating-dish; in the bottom is placed a thin sheet or mat of asbestos. It can be heated by alcohol or gas. The evaporating-dish is shallow, flat-bottomed and made of tin or aluminum, 3 inches in diameter and ¾ inch deep. The iron walls conduct the heat to all sides and the sample is uniformly heated throughout, thus preventing foaming and sputtering. With 10-gram samples, it is stated that at 300° F. the water can be evaporated in about 5 minutes if the plate is hot when the sample is placed on it. A hole is provided for the insertion of a thermometer so that the exact temperature of the oven may be known.

FIG. 37—BENKENDORF OVEN

In the Farrington or Wisconsin high-pressure oven (Fig. 37a), evaporation of water takes place at a temperature of 240° to 280° F. It consists of an iron oven with double walls between which steam enters under pressure of 60 to 80 pounds. The evaporating dishes are the same as those used in the Benkendorf oven,

four of which can be placed in the oven at the same time. The samples are heated until the residue appears brown, which takes from 30 to 60 minutes, depending on the amount of the sample and the temperature of the oven. A 10-gram sample can be dried at 260° F. in about 30 minutes; a 50-gram sample requires at least 60 minutes. It is a safe precaution to heat samples a second time to make sure that the water is completely evaporated, especially until one has had suffi-

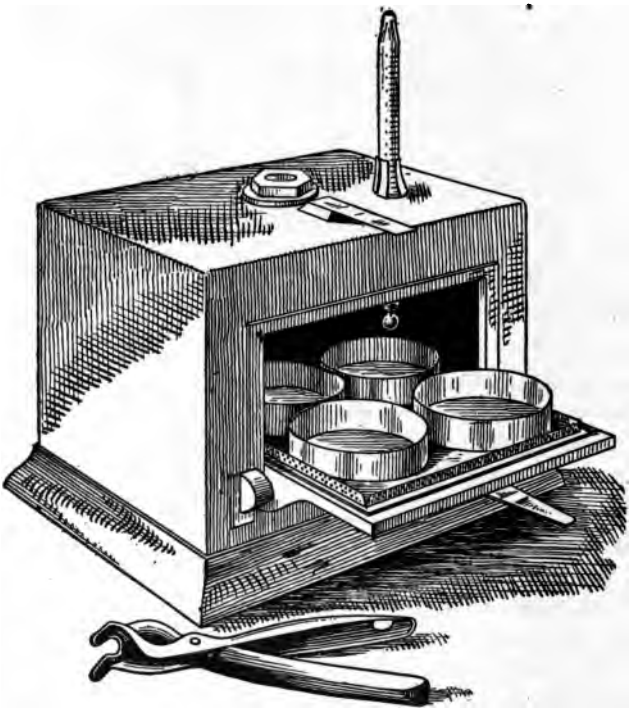


FIG. 37*a*—FARRINGTON'S HIGH-PRESSURE OVEN

cient experience to become familiar with the best working conditions.

In respect to accuracy, the results are satisfactory for creamery work, though some careful work indicates a tendency to high results, owing to sputtering and to decomposition of the butter at the high temperature used.

The apparatus has the following advantages: (1) It is well adapted to use in creameries because the heat is furnished by steam and the oven can be directly connected with the boiler, thus lessening danger from accidents by fire in comparison with the use of alcohol lamps. (2) The process does not require close attention during the evaporation, when once the operator becomes familiar with the management of the oven. (3) The temperature can be kept under control.

In this connection we mention the oven described by Dean (Dairy School at Guelph, Ontario, Can.), which is a steam-oven made of galvanized iron and able to withstand a pressure of 10 pounds. Complete evaporation requires 5 or 6 hours.

PATRICK AND IRISH MOISTURE-TESTS

These two methods are essentially alike. An aluminum cup containing the sample of butter is held by a hand-clamp directly over the flame of an alcohol lamp or gas-burner. In the test of Irish, a mirror is used to ascertain when the water is all evaporated, which calls for certain precautions (p. 113).

These two tests are rapid but usually give high results, though not enough so to make them unsuitable for ordinary work. In order to obtain reasonably ac-

curate results, the following precautions should be observed: (1) The cup should be heated gradually, since too rapid heating causes sputtering and loss. (2) During the evaporation, the dish should be shaken with a rotary motion in order to distribute the heat more uniformly and facilitate escape of water-vapor. (3) The butter must not be heated so high nor so long as to cause decomposition and volatilization of the butter-solids.

GRAY'S TEST FOR WATER IN BUTTER

This method was worked out in the Dairy Division of the Bureau of Animal Industry, U. S. Dept. of Agr. (Circular No. 100). It differs from the methods already described in several respects: (1) The water is evaporated from the butter in the presence of a slightly volatile mixture of high boiling-point, which does not mix with water. (2) The evaporated water is recovered by distillation. (3) The distilled water is caught in a graduated tube, which permits direct reading of the results in percentage of water in butter.

The apparatus and reagents employed in the test, aside from an accurate scale with a 5-gram and a 10-gram weight, an alcohol lamp and a 6-cc. measuring-graduate are (1) the special testing-apparatus, (2) parchment paper, perfectly dry, (5 by 5 inches in size), (3) rubber stoppers (one stopper lasts for about 100 tests), and (4) the amyl reagents (a mixture of 5 parts of amyl acetate and 1 part of amyl valerianate, entirely free from water-soluble impurities).

The special testing apparatus includes three essen-

tial pieces (1) a flask (A, Fig.37b), (2) a receiving-bulb with graduated tube (C, Fig. 37b), and (3) a condensing-jacket (E, Fig. 37b). The receiving-bulb is connected with flask A by means of a rubber stopper (B). G is a ground glass stopper fitting tightly into the tube above the graduated scale. When more than one apparatus is used, each stopper and tube should be properly marked so that each stopper shall always be used with its corresponding tube. Each mark of the graduated-scale represents 0.2 per cent. of water when a 10-gram sample of butter is used. The glass condensing-jacket (E, Fig. 37b) is connected to the graduated tube by a rubber stopper (D, Fig. 37b).

The operation of the test is carried out as follows: (1) Weigh a 10-gram sample by placing on each scale-pan one sheet of parchment paper and balancing; the sample is placed in center of paper on one pan, a 10-gram weight being in the other. (2) The paper with sample is folded in such shape as to slip without loss into flask A (which must always be clean and dry before use). Some prefer to weigh the sample of butter directly into the flask. (3) Then pour 6 cc. of amyl reagent into flask A, (4) connect the apparatus (which must be clean and dry always before use) in the manner shown in Fig. 37b, fill the condensing-jacket with cool water to within 1 inch of top (F, Fig. 37b) and *remove the glass stopper* (to prevent danger of bursting of tube by pressure of uncondensed water-vapor). (5) Then heat the bottom of flask A over the flame of the burner. The butter soon melts, mixes with amyl reagent, and later passes

as vapor into the graduated tube, where it is condensed, and then runs back into the receiving-bulb (C). The condensation in the graduated part of the tube must be carefully watched and the steam not allowed to go higher than the 15 cc. mark, in order to avoid risk of losing water. If it goes above this mark, remove the flask from the flame for a short time. If the mixture in flask A shows a tendency to foam over, remove the flame. In case of persistent foaming, cool the flask and contents, add about 2 cc. more of amyl reagent and continue heating. When the mixture in the flask becomes brown and all crackling noise ceases, the water has all been driven from the flask. This usually requires 5 to 8 minutes. (6) After completing distillation, flask A is disconnected from stopper B and the glass stopper G is *firmly* inserted in end of graduated tube. (7) The tube is then inverted, transferring the water from the receiving-bulb (C) into the graduated tube, care being taken not to allow any water to be lost through the small bent tube inside the bulb. The water is then poured from the condensing-jacket, after which the jacket may be removed. (8) Some amyl reagent is distilled with the water, but is easily separated as follows: Hold the receiving-bulb in the palm of the hand and the stoppered end away from the body; then raise to a horizontal position and swing at arm's length sharply downward to the side. This is repeated several times until the line of separation between the water and amyl reagent is sharply distinct, the amyl reagent rising above the water. The tube should then be held a short time with the stoppered

end downward and the amyl reagent in the bulb agitated in order to rinse down any water adhering to the sides of the bulb. (9) After cooling the tube and contents the percentage of water is read directly from the scale, when a 10-gram sample is used. The water is in the lower part of the tube. The reading is made to the lower part of the meniscus. When any amount of butter other than 10 grams is used, a corresponding correction must be made.

The accuracy of the results obtained by the Gray method depends upon several factors, chief of which are the following: (1) The graduation must be correct. (2) The amyl reagent must be pure. (3) The manipulation as described must be followed strictly. (a) Too rapid heating must be avoided in order to avoid the danger of driving water-vapor into the air from the upper end of the condensing-tube. (b) The rubber stopper B (Fig. 37b) must fit the neck of flask A perfectly and must be free from cracks. A loose-fitting stopper may allow loss of water either by escaping into the air or by collecting between the neck of the flask and the stopper. Repeated heating causes the rubber stoppers to crack

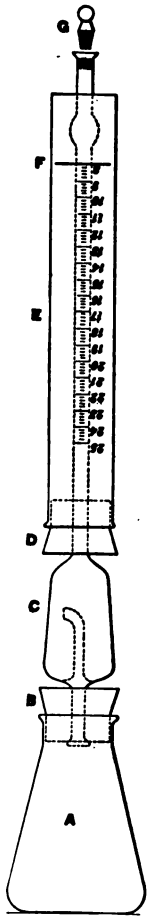


FIG. 37b GRAY'S APPARATUS READY FOR USE IN TESTING WATER IN BUTTER.

and they are then liable to collect and retain water in the cracks; this trouble may be remedied to some extent by rubbing the stopper thoroughly with amyl reagent before use each time. (c) The sample must be heated long enough to remove all water not only from the butter but from the flasks as well. Comparative tests reported by some workers indicate that more accurate results are obtained by heating the butter until black or nearly so.

One serious objection to the apparatus is that it is easily broken. This objectionable feature has been obviated in the Mitchell-Walker test (Eastern Dairy School, Kingston, Ontario, Can.), which utilizes essentially the principle of the Gray test; most of the parts are of metal and the manipulation is comparatively simple.

CHAPTER IX

Methods of Testing Butter for Salt

All methods for the determination of salt are based upon one principle. When a solution of silver nitrate and a solution of common salt (sodium chloride) are brought together, a chemical reaction takes place, by which the silver combines with the chlorine, forming silver chloride, which is a white precipitate or solid substance. Moreover, a given amount of silver always combines with a definite amount of chlorine. If, therefore, to a solution containing salt, we add a silver nitrate solution of known strength until the chlorine of the salt is all changed into the solid, white silver chloride, we can tell just how much salt is in the tested solution by keeping a record of the amount of silver nitrate solution used. One part by weight of salt requires for complete precipitation about 2.9 parts by weight of silver nitrate. The only point of difficulty is to know just when the chloride is all precipitated, but we have a simple, accurate way of telling precisely when this point is reached. A solution of potassium chromate also forms a precipitate when treated with silver nitrate but in this case the solid substance (silver chromate) is deep-red or brick-red in color. Furthermore, if we add silver nitrate solution to a solution containing both chloride and chromate, stirring or shaking vigorously during the addition, the chloride

will all be precipitated in the form of the white silver chloride before the brick-red silver chromate forms permanently.

How are the foregoing facts applied in finding the percentage of salt in a solution? For simplicity, we will use the following illustration experiments: Dissolve 29.06 grams of pure silver nitrate in pure water and then add enough more water to make just 1000 cc. of solution. (Standard silver nitrate solutions are best obtained ready-made from a reliable chemical-supply house.) One cubic centimeter of this solution is just equal to 0.01 gram of salt. Next dissolve 2 grams of salt in pure water to make 100 cc. of salt solution. In a cup or beaker measure 10 cc. of this salt solution and add 2 or 3 drops of a solution of potassium chromate (made by dissolving as much potassium chromate as possible in 100 cc. of cold water); then add slowly from a burette some of the silver nitrate solution and stir or shake the mixture in the cup. On the first addition of silver nitrate, the mixture becomes turbid from the formation of silver chloride and on further addition sooner or later there will appear a deep brick-red or blood-red coloration due to the formation of silver chromate. So long as any chloride is left in solution in the mixture, the red silver chromate will disappear on agitation. When the red color begins to become prominent, then run in only 0.1 cc. of silver nitrate at a time, agitating vigorously after each addition and continue until a faint reddish tinge colors the whole mixture and does not disappear on agitation. The color change can best be seen on a white background as in a white cup or a glass beaker set on white

paper. This means that the chloride has all become precipitated or changed to solid silver chloride, and that silver chromate is formed and remains in the mixture. When this point is reached, add no more silver solution. Examine the burette and read the number of cubic centimeters of silver nitrate solution that has been used. Suppose we find we have used 20 cc.; this means that the 10 cc. solution tested contains 0.20 gram of salt, since 1 cc. of silver solution precipitates the chlorine in 0.01 gram of salt. This is equal to about 2 per cent. of salt in the solution.

Several applications have been made for the determination of salt in butter, the difference in methods being the preparation of sample, strength of silver solution and amount of material taken for testing. At one time silver nitrate tablets were on the market.

It will probably be found best to purchase the silver nitrate solution from some reliable chemical-supply house. When, however, the solution is made at home from silver nitrate crystals purchased at a drug-store, only the pure compound should be used. In dissolving silver nitrate in water, it is best to use distilled water or rain-water. Water which produces any marked turbidity when treated with a few drops of silver nitrate solution should not be used in preparing silver nitrate solutions.

PERKINS TEST FOR SALT IN BUTTER

This was devised at the Ohio experiment station and can be carried out more quickly than other methods.

The solutions used are: (1) A solution of silver

nitrate containing 29.06 grams per liter; (2) commercial acetone (or equal parts of denatured alcohol and ordinary ether); (3) saturated water solution of potassium chromate. The apparatus required is a 50 cc. burette, accurately graduated to 0.1 cc., together with a white cup or beaker.

The operation of the test is performed as follows: Weigh in a cup or beaker 5 or 10 grams of butter from a sample prepared as previously directed (p. 101). Warm gently until just melted and then add 20 or 30 cc. of commercial acetone (obtainable at any good drug-store) or, if acetone is not easily obtainable, use the mixture of denatured alcohol and ether; add about 1 cc. of the chromate solution, and then run in slowly from the burette the solution of silver nitrate, vigorously stirring or shaking the mixture. Continue to add the silver solution until the brick-red color remains permanent for a minute or more after thorough agitation. Each cubic centimeter of silver nitrate solution used represents 0.1 per cent. of salt in the butter when a 10-gram sample of butter is taken, and 0.2 per cent. with a 5-gram sample. For example, if 25 cc. are used, the result would be 2.5 per cent. of salt in the butter when a 10-gram sample is taken.

This test can be applied in connection with the determination of water by most methods. Thus, the dried residue obtained with the Cornell, Wisconsin, Ames, Patrick and similar methods can be used for salt determination by adding a small amount of water and carrying out the operation described in the preceding paragraph.

SHAW TEST FOR SALT IN BUTTER

This test is carried out in connection with Shaw's method for determining fat in butter (p. 103).

The solutions are a silver nitrate solution containing 14.525 grams of pure silver nitrate per liter (just one-half the strength used in the Perkins test) and a 10 per cent. solution of potassium chromate. Besides the 50 cc. burette and a beaker or white cup, as in the Perkins test, there are required a volumetric flash with a 250 cc. mark and a 25 cc. pipette.

To determine the percentage of salt in butter in connection with that of fat, a solution of the salt contained in the butter is obtained in the manner described in paragraph 4 (p. 106), the wash-water being allowed to run into the 250 cc. flask and the operations in paragraph 4 are performed three times instead of once, the wash-water each time being run into the flask.

When the washings have become cool, the flask is filled to the mark with cold water and shaken until the contents are well mixed. Then measure with the pipette 25 cc. of the wash-water (representing 2 grams of the original sample or one-tenth of 20 grams) into the cup or beaker, add 2 or 3 drops of chromate solution and then run into the mixture from the burette the silver nitrate solution, stirring constantly, until the permanent reddish tinge appears.

The silver nitrate is of such strength that 1 cc. represents 0.005 grams (or 0.5 per cent.) of salt in butter when a 1-gram portion is used, 0.25 per cent, where a 2-gram portion is taken, etc. In the foregoing description, 2 grams are represented and we, therefore,

obtain the percentage of salt in the original sample by dividing the number of cubic centimeters of silver nitrate solution used by 4. For example, if the burette reading shows that 10 cc. of the silver solution are used, then 10 divided by 4 equals 2.50, which is the percentage of salt in the sample of butter tested.

WISCONSIN TEST FOR SALT IN BUTTER

Sammis adapts the general method to creamery use as follows: Dissolve 5.1 grams of pure silver nitrate in pure water to make 250 cc. of solution. Each cubic centimeter of this solution represents 1 per cent. of salt when we use 17.6 cc. of the wash-water, which is obtained by shaking 10 grams of butter with 250 cc. of clean, warm water. The test is then carried out in the manner described in connection with the preceding tests.

CHAPTER X

Methods of Testing the Acidity of Milk and Milk Products

It is often necessary to know how much acid is present in milk, cream, whey, etc. The amount of acid in milk may be a suggestive indication of the age of milk and of its care. In butter-making, the uniformity of the product depends largely upon the ripening of cream, which can be well controlled only by knowing its acidity. In cheese-making, it is at times important to know whether milk contains too much acid and it is also quite essential to have some knowledge of the amount of acid present in the milk and whey at different stages of the operation.

THE CAUSES OF ACIDITY IN MILK AND ITS PRODUCTS

We may distinguish two kinds of acidity in milk and its products: (1) Apparent acidity, and (2) acidity due to lactic acid. The *apparent* acidity is due to the presence in normal milk of casein and acid phosphates, which have the power, like free acids, of neutralizing alkalis. This apparent acidity in fresh milk is about .07 or .08 per cent. on the average. It varies with different conditions, increasing, for instance, with advance of lactation.

Acidity due to lactic acid is formed in milk after it is drawn, and is caused by the action of certain forms

of bacteria upon milk-sugar. In general, when milk contains over .10 per cent. of acid, it may safely be assumed that it contains some lactic acid. The amount of lactic acid present in milk may be approximately found by subtracting .10 from the total amount of acid apparently present. However, in speaking of the acidity of milk, we usually mean the total acidity, and not that due to lactic acid alone. One can not commonly detect a sour taste in milk that has a total acidity under .3 per cent.

GENERAL PRINCIPLES OF TESTING ACIDITY

The method of determining the amount of acid in milk and its products is based upon the well-known chemical action taking place between acids and alkalis. Whenever we bring together in solution an acid and an alkali, they combine with each other and form a third compound, the acid and alkali disappearing as such. The acid and alkali are said to *neutralize* each other and the process is called neutralization. For example, if we add together some hydrochloric (muriatic) acid and sodium hydroxide (caustic soda) in right proportions, we shall have neither hydrochloric acid nor caustic soda, but a new compound, sodium chloride (common salt), which has been formed by the action of the acid and alkali upon each other. The hydrochloric acid used in the experiment tastes sour and biting, while the caustic soda solution has a peculiar odor, feels soapy on the skin, and, if strong enough, destroys the skin. After these two compounds are brought together in proper proportions, there is no

longer observed any sour taste of acid or soapy feeling or odor of alkali, because the acid and alkali have neutralized each other and have combined to form simply common salt, the presence of which is noticed by its taste. The solution is said to be neither alkaline nor acid, but neutral.

USE OF INDICATORS IN TESTING ACIDITY

In working with acids and alkalis, it is necessary to have some simple means of knowing when a solution is acid, alkaline or neutral (neither acid nor alkaline). This can be found by using some substance, called an indicator, which is so acted on by alkalis and acids as to undergo changes of color, being changed one color by alkalis and a different color by acids. One substance which finds wide use as an indicator is a chemical compound called *phenolphthalein*, a solution of which is turned pink by alkalis and colorless by acids. For use in testing acidity, one dissolves 10 grams of the dry powder in 300 cc. of 90 per cent. alcohol, or 5 grams in 100 cc. of 50 per cent. alcohol, adding one or more drops of dilute alkali until the solution is slightly pinkish in color. It is necessary to use only 5 or 10 drops of this solution as indicator.

GENERAL APPLICATION OF PRINCIPLES OF NEUTRALIZATION

What use can be made of the foregoing facts in finding the per cent. of acid in a solution? For simplicity, we will use the following illustrative experiment: In a glass or teacup we put 100 cc. of a solution containing .25 per cent. of lactic acid and add 5 or 10 drops of indicator solution. Into this mixture

we run from a graduated cylinder or burette some *standard solution* of caustic soda, prepared by dissolving 4 parts by weight of pure caustic soda in 1,000 parts of distilled water. This solution of caustic soda we add, a little at a time, to the solution of lactic acid, stirring or otherwise agitating the mixture thoroughly after each addition. The pink color that appears when the caustic soda solution is added disappears on stirring. After the alkali has been added several times, the color disappears less rapidly each time. The gradual addition of the alkali is continued until finally the pink color does not disappear readily on continued agitation but remains for some moments. The neutralization of the acid by the alkali is complete, and the addition of alkali stops at this point. The appearance of the pink color throughout the body of the liquid means that enough alkali has been added to combine with the lactic acid, and a little more, one drop of the alkali solution being enough to produce the pink color with the indicator after the acid is neutralized. The liquid in the cup contained at the start only a solution of lactic acid. As soon as we added alkali, it combined with the lactic acid, forming the neutral compound, sodium lactate. We then had a mixture of lactic acid and sodium lactate. As we continued to add alkali, the amount of sodium lactate increased, while the amount of lactic acid decreased. Finally, a point is reached when the solution in the cup contains no free lactic acid, but only sodium lactate, and the addition of one more drop of alkali turns the indicator pink, producing a more lasting coloration throughout the solution and showing that the acid

has been completely neutralized, that is, changed into sodium lactate.

Having completed the neutralization of the acid, we examine the burette or the graduated cylinder containing the alkali to find exactly how much alkali solution has been used in neutralizing the acid. The lactic acid has required, say, 28 cc. of soda solution. Each cubic centimeter of alkali neutralized by acid corresponds to .009 gram of acid, and 28 cc. would therefore correspond to .25 gram of lactic acid. This amount of lactic acid in 100 cc. is .25 per cent. The process of making a chemical determination by means of a standard solution is known as *titration.*

NEUTRALIZATION METHOD APPLIED TO TESTING ACIDITY OF MILK AND MILK PRODUCTS

In practical dairy work, one is freed from the necessity of preparing standard solutions, except in a simple way, and the calculations needed to figure the results are direct and easy. The caustic soda solution is prepared in such strength that 1 cc. of it equals .1 or 0.01 per cent. of lactic acid, when a certain amount of milk or other substance is used. All tests for the acidity of milk and its products are based upon the general principles previously described and differ from one another simply in some of the details of carrying out the process. There are now available several forms of so-called acid tests.

The essential apparatus and reagents for determining acidity in milk and its products are the following: (1) An accurately graduated burette or cylinder for measuring the amount of standardized alkali solution used;

(2) a pipette for measuring the amount of milk, cream, etc. to be tested; (3) a white cup or glass beaker for holding the milk, cream, etc. during titration, that is, while the alkali is running into the liquid tested; (4) a glass or gutta-percha stirring-rod, with which to stir the mixture during the titration; (5) a standardized alkali solution; (6) solution of phenolphthalein in alcohol to indicate when the liquid tested becomes alkaline (p. 132). (7) a liter flask or graduate for making up alkali solution. Some of these essentials we will consider in more detail.

The Burette should be accurately graduated and the smallest divisions should be 0.1 cc. at least. The size of the burettes in use varies. A common and convenient size is one that holds 50 cc. When the amount of solution taken for testing is small (not over 9 grams), a 10 cc. burette can be used.

The Pipette most easily available is the ordinary 17.6 cc. pipette used in milk testing. Some of the tests use a 50 cc. pipette; others, 8.8 cc.

Standardized alkali solution,—This usually consists of pure sodium hydroxide (caustic soda) dissolved in pure water (distilled water should always be used if possible). It must be prepared so as to be of exact, known strength. We will consider this solution in respect to (1) different strengths used, (2) methods of preparation, and (3) precautions in keeping.

(1) *Different strengths used.*—The alkali solution differs in strength in different forms of tests, usually being one-tenth normal ($\frac{n}{10}$) or one-fiftieth normal ($\frac{n}{50}$). A tenth-normal alkali solution is of such strength that 1 cc. neutralizes 0.009 gram of lactic acid.

If, therefore, an 18-gram (17.6 cc.) sample is used for testing, 1 cc. of tenth-normal alkali solution corresponds to 0.05 per cent. (one-twentieth of one per cent.) of lactic acid in the solution tested; 0.1 cc. of alkali solution corresponds to 0.005 (one two-hundredth of one per cent.) of acid. When a 9-gram sample is used, 1 cc. of tenth-normal alkali solution corresponds to 0.1 per cent. (one-tenth of one per cent.) of lactic acid in the solution tested; and 0.1 per cent. of alkali corresponds to 0.01 per cent. (one one-hundreth of one per cent.).

In a one-fiftieth normal solution, 1 cc. of alkali corresponds to 0.0018 gram of lactic acid. Therefore, in case of an 18-gram (17.6 cc.) test sample, 1 cc. of such alkali solution corresponds to 0.01 per cent. (one one-hundredth of one per cent.).

(2) *Methods of preparation.*—The standard alkali solution is obtained in one of several ways. (1) It can be purchased ready-made in any strength desired from dairy-supply or chemical-supply houses. It costs most in this way. (2) The chemically pure dry sodium hydroxide (caustic soda) can be purchased from reliable chemical-supply houses in exact amounts and dissolved in water. This should be the cheapest way of obtaining the alkali solution. For example, 4 grams of the pure compound dissolved in 1000 cc. (1 liter) of water makes a tenth-normal solution; 40 grams dissolved in 1000 cc. of water makes a normal solution; and 100 cc. of this normal solution, diluted to 1000 cc. makes a tenth-normal solution or, diluted to 5000 cc. makes a fiftieth-normal solution. (3) The normal alkali solution can be purchased and made to any

desired strength by dilution. (4) Alkali tablets and powders containing a definite amount of carbonate can be purchased and dissolved according to directions.

In preparing alkali solutions, observe the following precautions: (a) Measuring.—The measuring-flask or graduated cylinder used in making dilutions must be accurate. (b) Water used for dilution.—The water used must be neither acid nor alkaline; water carefully distilled and kept free from impurities should always be used, if possible; next best is clean rain-water. (c) Use of dry alkali—When pure sodium hydroxide (caustic soda) is used, it must be carefully transferred *without loss* from the bottle to the vessel in which solution and dilution are to take place; the bottle is rinsed with water several times, the rinsings being poured into the vessel holding the alkali. The dissolving of caustic soda in water produces heat and the solution should be allowed to cool to room temperature before it is finally diluted to the desired mark. Bottles containing alkali in the dry form should come tightly sealed, and be kept so, and should not be opened until the solution is to be made. It is necessary to use the entire contents of the bottle at one time. (d) Use of concentrated alkali solution.—When a normal alkali solution is purchased and diluted, the same precautions must be observed as when the dry form is used.

(3) *Precautions in keeping alkali solution.*—The alkali solution should be kept from contact with air in order to prevent weakening by absorption of carbon dioxide and moisture. A weakened alkali solution has the effect of giving higher results of acidity than the

truth. Several forms of bottle have been devised which reduce this danger to a minimum; some of these are illustrated in Figs. 39, 39a and 39b.

OPERATION OF TESTING FOR ACIDITY

Before describing details of any of the methods in use, we will briefly consider some of the principal points that apply to all methods. From the material to be tested measure the amount desired into a cup or beaker; nothing is better than a white china tea-cup. The pipette is rinsed by filling it with water, which is added to the material in the cup. The addition of water to the sample to the extent of three or four volumes will enable one to see the pink coloration at the end more sharply. Then add 5 to 10 drops of the phenolphthalein solution, and from the burette filled with alkali run small portions into the mixture in the cup, stirring thoroughly after each addition. A pink color soon appears but disappears on stirring. The addition of alkali in small amounts at a time is continued with care; sooner or later, according to the amount of acid present, it will be noticed after each addition of alkali, that the pink color disappears more slowly showing that the acid is becoming nearly neutralized. When the color disappears quite slowly, add the alkali not more than one drop at a time. Finally, a point is reached when, after the addition of one drop of alkali, the pink color does not disappear even after stirring 20 to 30 seconds. This indicates that the acid is completely neutralized. Add no more alkali. The pink color will disappear after standing some time, even when the solution is alkaline. Some experience

enables one easily to know when the pink color is sufficiently permanent. It is very helpful in recognizing the point of neutralization to have some color-standard with which to compare the pink color obtained on neutralization; it also insures greater uniformity in results. For this purpose a color-standard can be prepared in the manner described on page 192. The number of cubic centimeters of alkali used is then read from the burette.

Calculation of results.—The percentage of lactic acid in the material tested can be calculated from the following rule: Multiply the number of cc. of alkali used by the amount of lactic acid neutralized with 1 cc. of alkali (0.009 in case of tenth-normal solutions, and 0.0018 in case of fiftieth-normal solutions); divide the result by the amount of sample used in the test (9, 18, etc.) and multiply the last result by 100. This rule may be expressed by the following formula:

$$\text{Per cent. of acid} = \frac{\text{c.c. alkali} \times \text{acid equivalent of 1 c.c. alkali}}{\text{Amount of sample used for test}} \times 100$$

It makes comparatively little difference in the results whether the figure representing the amount of sample used is given in the form of grams or cubic centimeters. The difference amounts to only .02 or 0.03 per cent. ordinarily.

Some needless confusion has been introduced by stating the results in the form of "degree of acidity," one degree meaning 1 cc. of tenth-normal alkali solution neutralized when a certain amount of material is taken for testing. In the dairy literature of Europe,

much confusion exists in this respect, the meaning of a "degree" varying according to the method used. It seems highly desirable on all accounts always to state the results of acidity determination in terms of percentage of lactic acid; this method now practically prevails in America. In most of the tests in common use, no calculations or only very simple ones, have to be made, because the amount of material taken and the strength of alkali used are such as to enable one to read the results in direct percentage from the burette, as we have already noticed (p. 137).

METHODS USED IN TESTING ACIDITY

After having considered the general principles and their application, we do not need to describe the different methods in detail further than to point out the distinctive features of each, since the really essential features are the same in all.

Van Norman's method (Bulletin No. 104, Purdue Univ. Agr. Exp. Sta., 1905) is based upon the use of a fiftieth-normal solution of alkali, prepared by diluting 37 cc. of normal solution of sodium hydroxide (caustic soda) to 1850 cc. (or 20 cc. of normal solution to 1000 cc.), observing precautions already pointed out (Fig. 38). The normal solution must be of guaranteed accuracy and should be obtained only from a reliable chemical or dairy-supply house. The amount of milk, cream, etc. used in testing is that measured by a 17.6 cc. pipette. The alkali may be run into the cup containing the material to be tested either from a burette or from a 100 cc. graduated cylinder until the characteristic pink tint is obtained (p. 139).

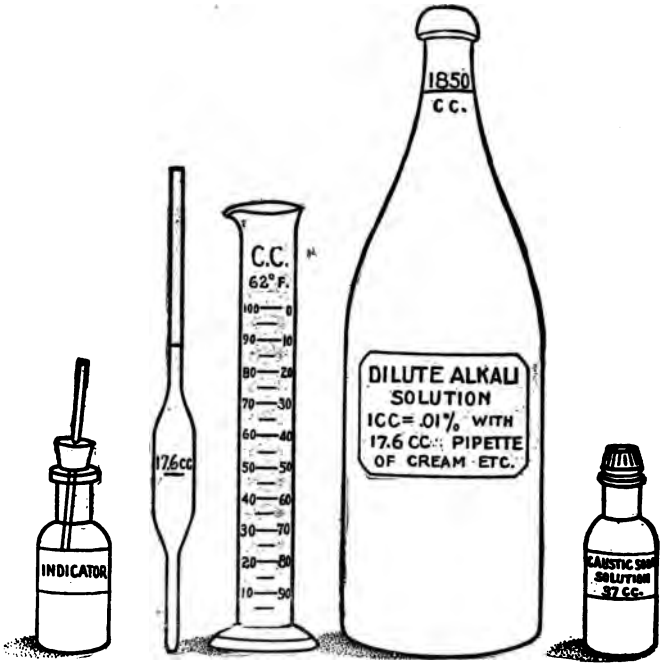


FIG. 38—VAN NORMAN ACIDITY TEST

Each cubic centimeter of alkali solution used corresponds to 0.01 per cent. of acid. Thus 40 cc. of alkali solution equals .40 per cent. of acid in the material tested.

Farrington's alkali-tablet method (Fig. 38a) makes use of tablets containing the alkali and indicator mixed together; one tablet contains enough alkali to neutralize 0.035 gram of lactic acid. When 5 tablets are dissolved in 97 cc. of water, a fiftieth normal solution is furnished, each cubic centimeter of which is equal to 0.01 per cent. of lactic acid when a 17.6 cc. sample of ma-

terial is taken for the test. In making the test, the solution is poured from a 100 cc. graduated cylinder.

In preparing the alkali solution, 5 tablets are put into the 100 cc. cylinder which is then filled to the 97 cc. mark with clean, soft water, preferably distilled. The cylinder is then tightly stoppered and laid on its side until the tablets dissolve, which requires several hours. The cylinder must be kept tightly stoppered so that none of the solution can be lost while the tablets are dissolving. A slight flocculent residue, consisting of some inert matter used in making the tablets, will not dissolve. The solution should always be shaken well before using. When not in use, it should be kept tightly stoppered. Solutions that have been prepared longer than a week may change in strength and it is better to prepare fresh solutions than to use old ones. The solid tablets do not change if kept dry.

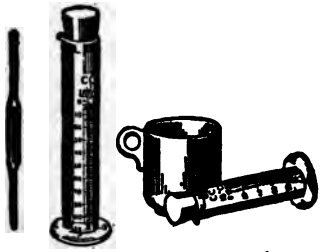


FIG. 38a—FARRINGTON'S ALKALINE-TABLET TEST FOR ACIDITY

Spillman's Modification of Farrington's Test

The apparatus consists of an ordinary teacup, a regular 17.6 cc. pipette, a quart Mason fruit-jar, and "Spillman's acid-test cylinder" (Fig. 38b). The alkali solution is prepared by dissolving alkaline tablets in water at the rate of 5 tablets for one cylinder of water filled to the mark 8, the solution being made and kept

in the fruit-jar. Observe the precautions given above in using tablet solutions. In making the test, put 17.6 cc. of the material to be tested in a teacup, pour into the cup the alkali solution in the manner described above, until the pink color remains. Then pour the contents of the teacup into the Spillman cylinder and read the scale at the surface of the liquid in the cylinder. The results indicate the acidity in tenths of one per cent. The cylinder reads as high as 8 tenths.

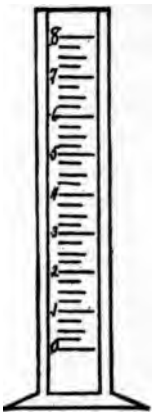


FIG. 38*b*
SPILLMAN'S ACID-TEST CYLINDER

Alkaline Tablet Test Modified for Rapid Estimation of Acidity

It is often desirable to ascertain quickly whether milk or cream contains more or less than .2 or .3 per cent. of acid. Farrington and Woll have devised the following method: An alkali solution is prepared by dissolving in an 8-ounce bottle 2 tablets for each ounce of water used. A No. 10 brass cartridge shell, on which a wire handle is soldered, is used for measuring the sample to be tested and also the alkali. A cartridgeful of milk or cream is placed in a teacup and then a cartridgeful of the alkali solution is added. The contents of the cup are mixed by a rotary motion. If the sample tested remains white, it contains over .2 per cent. of acidity; if a pink color remains, the acidity is less than .2 per cent. The intensity of the pink color indicates the relative amount of acid present, since the color

will be more intense in proportion as there is less acid. Any other measure may be used in place of the brass cartridge-shell, but in every case care must be taken to use equal amounts of milk or cream and of alkali solution.

Publow's method (Fig. 39a) is fully described in Circular No. 7, Cornell University Experiment Station, 1909. The alkali solution is tenth-normal, prepared by diluting 50 cc. of a special solution (containing 9.2 grams of pure caustic soda) to 2300 cc. In making the test a 9-gram sample is used, the test being carried out in the usual way. The burette used holds 10 cc. Each cubic centimeter of alkali solution used represents 0.1 per cent. of acid in the material tested.

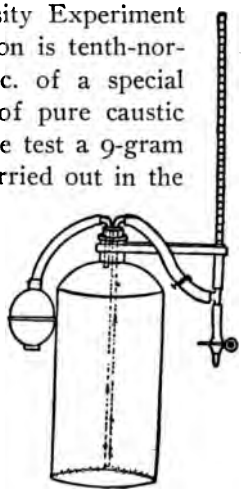


FIG. 39—CONVENIENT APPARATUS FOR ACIDITY-TESTING

Marschall's method like Publow's uses a 9-cc. sample and a tenth-normal solution of alkali, (called "neutralizer"). The characteristic feature of the method is a combined burette and bottle for holding the alkali solution (Fig. 39b). The burette is graduated to 0.2 cc. The reading represents 0.1 per cent. of acid for each cubic centimeter of alkali solution used. The alkali is also furnished in dry form in connection with this test, the contents of one package making 1000 cc. of tenth-normal alkali.

Manns' method uses a so-called "neutralizer," which is simply a tenth-normal solution of sodium hydroxide

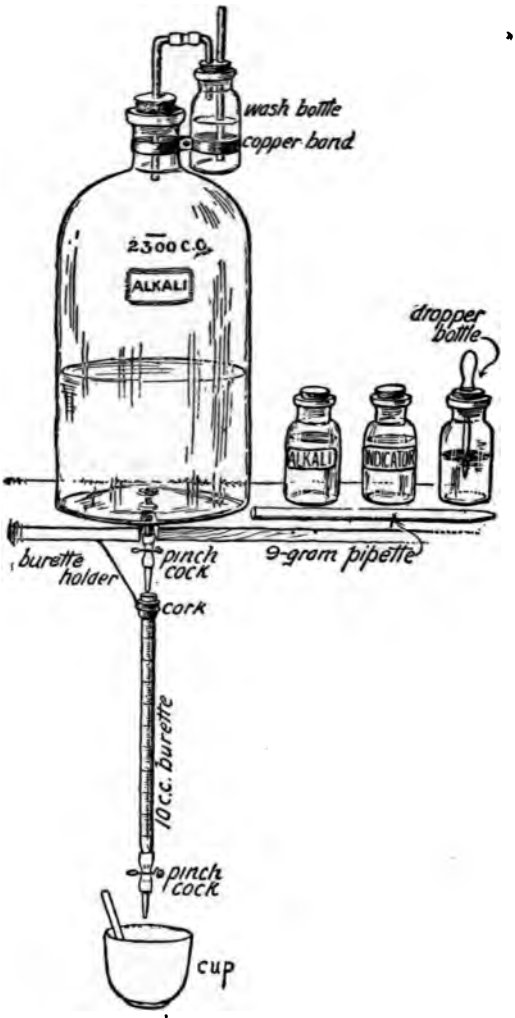


FIG. 39a—PUBLOW'S APPARATUS FOR ACIDITY-TESTING

(caustic soda), a 50 cc. burette and 50 cc. of the sample to be tested. The operation is carried out in the usual manner (p. 139). To calculate the results

FIG. 39*b*—MARSCHALL APPARATUS FOR ACIDITY-TESTING

into percentage of lactic acid in the material tested, multiply the number of cubic centimeters of alkali used by 0.018. The method as originally given is inconvenient and much less used than formerly. The cost of transportation of so dilute a solution of alkali is needlessly increased in comparison with tablets or normal

solutions and the large amount of material used (50 cc.) is not only inconvenient and time-wasting but calls for the use of larger amounts of alkali than are necessary. It is much better to use not more than a 9-gram sample and then the reading can be made direct; each cubic centimeter of solution representing 0.1 per cent. of lactic acid, or, if a 17.6 cc. sample is used, the reading is divided by 2.

TESTING THE ACIDITY OF WHEY

Whey may be tested by any of the methods described. Owing to the comparatively low acidity of whey in the operation of cheese-making, it is desirable either to have the alkali dilute (1 cc. of alkali equal to .01 per cent. acid), or else to take twice as much whey for testing as in the case of cream, the final results being corrected by dividing by 2. The whey should be free from particles of curd, since curd has the power of neutralizing alkali to some extent. The percentage of acid in milk can be used as a guide in ripening the milk before adding rennet, in the rate of heating (cooking) the curd, in the regulation of the piling of the curd, in the time of milling, etc.

TESTING THE ACIDITY OF CHEESE

From a sample of cheese, prepared in the manner described on page 108, weigh 9 grams and to this add water at a temperature of 100° to 110° F. until the volume equals 90 to 100 cc. Agitate vigorously and filter. To the filtrate add alkali solution, each cubic centimeter of which equals .01 per cent. of lactic acid, carrying out the test as with milk, cream, etc.

The number of cubic centimeters of alkali used, multiplied by 2, equals the per cent. of acid in the cheese. Much higher results are obtained if one treats the cheese instead of its water extract with alkali, because the nitrogen compounds of the cheese neutralize alkali.

RELATION OF FAT IN CREAM TO ACIDITY OF CREAM-RIPENING

Cream rich in fat ripens, that is, becomes acid, more slowly than cream poor in fat. This is so, because the larger the percentage of fat in cream the smaller is the percentage of sugar, and the sugar is the source of lactic acid. The favorable influence of ripening upon the process of churning is believed to be due to the action of the acid upon the calcium casein of the cream, converting it into calcium lactate and so lessening its tenacious hold upon the fat-globules in emulsion. The fat itself of the cream is not changed. The amount of acid to be formed in cream-ripening is, therefore, to be governed more by the amount of calcium casein in the cream than by any other constituent. The less fat there is in normal cream, the more casein there will be, and the greater the per cent. of acidity needed. The more fat there is in cream, the less calcium casein there will be, and the less the amount of acid needed. These statements conform to practical experience. Thus, it is found that in cream containing 25 per cent. of fat, it is necessary to produce nearly .7 per cent. of acid in order to get the results sought by ripening, while, in cream containing 35 per cent. of fat, less than .6 per cent. of acid is sufficient.

To ascertain how much acid should be formed in

cream before churning, the following rule is suggested by Van Norman (Bulletin 104, Purdue Univ. Agr. Exp. Sta.): From 100 subtract the per cent. of fat in the cream tested and multiply the result by .9, or, expressed as a formula, (100 — per cent. of fat in cream)×.9. For example:

Cream with 20 per cent. fat requires .72 per cent. of acidity.

Cream with 25 per cent. fat requires .67 per cent. of acidity.

Cream with 30 per cent. fat requires .63 per cent. of acidity.

Cream with 35 per cent. fat requires .58 per cent. of acidity.

The use of .9 as a factor for multiplying may not suit all conditions and some other factor, .8 for example, may be used. Each operator may experiment and easily find what per cent. of acidity is best adapted to the production of the butter suiting his market, and then a table like the above can be made, using .9 or some other factor.

OUTLINE STATEMENT OF SOME SPECIAL PRECAUTIONS IN TESTING ACIDITY

1. The material to be tested for acidity must be thoroughly mixed before sampling for a test.

2. The water used in preparing the alkali solution and in rinsing the pipette should be neither acid nor alkaline and should be soft and clean. Use distilled water if possible. The standard solution must be of the exact strength desired.

3. The alkali solution, in whatever form used, must be kept from contact with the air as much as possible to prevent changing strength.

4. When alkaline tablets are used, prepare a fresh solution in order to be sure of its strength, if there is any reason for uncertainty.

5. The alkaline tablets should be kept dry in well-stoppered bottles.

6. The tests should be made in a good light so that one can easily see the appearance of the longer-lasting pink color at the end of the reaction.

7. The appearance of the pink color at the end of the test can usually be more sharply seen by diluting the material examined with three or four times its volume of distilled water.

CHAPTER XI

Methods of Testing the Sanitary Condition of Milk

In addition to the compounds contained in normal milk (see Chapter I.), milk, as ordinarily produced and handled, contains other constituents, such as living organisms (especially bacteria), enzyms, and often other products due to abnormal physiological processes in the udder. These constituents affect the value of milk as food and as material for the preparation of dairy products, such as cream, butter, cheese, etc. The presence of micro-organisms, chiefly bacteria, and of enzyms brings about biochemical or fermentation changes in the normal constituents of milk, which affect its healthfulness and keeping quality. Undesirable ferment-producing constituents and products of fermentation have their origin in dirt and disease. It is important, therefore, to be able, as far as possible, to detect the presence of such undesirable constituents in milk. The method chiefly relied upon for determining the condition of milk in relation to biochemical factors has been by means of thorough bacteriological examination, which is practicable only in the hands of a specialist furnished with adequate equipment. There are, however, other methods for ascertaining the sanitary condition of milk which are available in the hands of any careful worker and which afford most helpful suggestions in regard to the value of

milk in relation to its use either as food or as material for the manufacture of dairy products; and some of these methods have not yet been utilized as fully as they ought to be.

The methods of testing milk in relation to its biochemical or sanitary condition will be considered under the following headings: (1) Acidity, (2) fermentation tests, (3) enzyms, (4) heated milk, (5) dirt in suspension.

RELATION OF ACIDITY TO SANITARY CONDITION OF MILK

The details of the quantitative methods of determining acidity in milk by titration with standardized alkali solution have been given already (pp. 131-148). For exact results, one of the methods given should be used. There are, however, some very simple tests which can be used for rough or preliminary work under conditions that do not permit exact work. Three of these tests we will describe, (1) the boiling test, (2) the alcohol test, and (3) the alizarol test.

Boiling test for acidity in milk.—A small amount of milk (10 to 20 cc.) is placed in a test-tube or beaker and brought to boiling. If it coagulates, the presence of more than 0.26 per cent. of acid is indicated, since normal milk coagulates on boiling when it contains about 0.26 per cent. of lactic acid.

Alcohol test for acidity in milk.—Equal parts (5 to 10 cc.) of milk and alcohol (specific gravity, 0.89) are mixed in a test-tube, and shaken vigorously. Fresh, normal milk shows no change, while old milk and milk from diseased udders show more or less coagulation

in flakes of casein, the size of the flakes depending on the acidity. There is no close relation between this test and real acidity of milk, though commonly milk containing more than 0.21 per cent. of acid gives a marked precipitation with alcohol.

Alizarol test for acidity.—This is a modification of the alcohol test but is more useful. The solution used is prepared by adding to the alcohol small amounts of alizarine (di-oxy-anthraquinone), the mixture being shaken repeatedly until a perfectly clear solution of dark reddish-brown color is formed. The solution is of right strength when 2 cc., added to an equal amount of fresh normal milk, gives an intense reddish color, similar to lilac or red-clover blossoms. This solution is very sensitive to acids, the color depending on the degree of acidity, as shown by the following statement of Morres: With fresh, normal milk having 0.16 per cent. of acidity, the color is lilac-red; with 0.18, pale-red; with 0.20, brownish-red; with 0.22, reddish-brown; with 0.25, brown; with 0.27, yellowish-brown; with 0.31, brownish-yellow; with 0.36 or over, yellow.

The degree of acidity is, to some extent, an indication of the age of milk, the temperature at which it has been kept, the condition of care exercised in keeping it clean, and of the abundance of lactic acid bacteria.

The acidity of market milk should usually be under 0.15 per cent. when it reaches the consumer, and should not exceed 0.2. The same may be said of milk that is intended for the purpose of cheese-making.

FERMENTATION TESTS IN RELATION TO SANITARY CONDITION OF MILK

Milk frequently contains objectionable forms of organisms or ferments that are not made perceptible by ordinary methods of observation. The condition arises particularly in milk used for cheese-making and may result in serious injury to the quality of the cheese. Several different forms of taste have been proposed which will enable one to detect the presence of certain types of organisms through the results of their biochemical action. Of the different forms we will describe two, (1) the Wisconsin test and (2) that of Gerber.

Wisconsin fermentation or curd test.—The Wisconsin Experiment Station (Wis. Exp. Sta. 12th and 15th Annual Reports, 1895 and 1898) has applied certain principles to the development of a test that enables one to identify milk containing certain forms of undesirable ferments likely to do serious injury. This method is based, in general, upon the plan of making conditions favorable for the rapid development of the ferments present in milk.

Apparatus.—The apparatus consists of the following parts: (1) Pint glass jars or tin cans with covers; (2) a well insulated tank to hold the jars, (3) rennet extract, (4) a thermometer, (5) a case-knife or similar instrument for cutting curd, and (6) a small pipette for measuring rennet-extract.

Operation of test.—The test is conducted as follows: The jars, including covers, just previous to use, are sterilized with live steam, scalding water or dry heat (212° F.). Each jar or can is filled about

two-thirds full with the milk to be tested and the sterilized cover put on at once. The jars are then placed in the tank which is filled with water at 100° to 102° F. up to the upper surface of the milk in the jars. The temperature of the water should be kept at 100° to 102° F. during the whole operation. To hasten the warming of the milk, the jars are taken out and shaken occasionally. The temperature of the milk is observed with a sterile thermometer, and when the milk has reached 98° F., one adds 10 drops of rennet-extract to each jar and mixes thoroughly by giving the contents of the jar a rotary motion. When the milk has coagulated, it is allowed to stand until it is firm, usually about 20 minutes. To enable the whey to separate more readily, the curd is then cut fine with a thin knife, which must be carefully rinsed with hot water after finishing each jar and before using it in another, in order to avoid carrying contamination from one milk to another and spoiling the test. The curd is allowed to settle completely. When the whey has been separating half an hour, the samples are examined for flavor by smelling, after which the whey is carefully poured out of the jars and this is repeated at intervals of 30 to 40 minutes for 8 hours or more. Under the favorable conditions of temperature, similar to those employed in cheese-making, the organisms present develop readily and reveal their presence in different characteristic ways. The jars are finally opened, any whey present is drained off, and the following tests are applied: (1) The curd is cut into two pieces. The curd will be solid and free from holes on the cut surfaces, if the milk is not

tainted. If it is spongy and full of holes, it contains those undesirable organisms that produce gases in the curd and injure it for cheese-making, showing in the form of "floating curds" and "huffy" cheese. The holes are usually small, their common name being "pin-holes." (2) The curd is examined with reference to any marked disagreeable odors that may be present. Some undesirable organisms reveal their presence by smell without making spongy curd. This may, perhaps, be best perceived by smelling of a freshly cut surface of the curd. Offensive odors are, of course, an undesirable indication. Special apparatus for performing the test is furnished by dairy-supply houses, but pint fruit-jars and other home-made appliances will answer satisfactorily.

By this method one can learn what particular lot of milk among several is responsible for undesirable fermentations. Moreover, having traced the source of contamination to a single herd of cows, it is easily possible, applying the test to single cows, to ascertain which individual or individuals may be the source of trouble.

Precautions.—Two points must be carefully observed in carrying out this test: (1) The temperature must be kept as near 98° F. as possible, in order that the bacteria may develop as desired. This can be done by keeping the temperature of the water surrounding the jars at 100° to 102° F. The temperature must be watched. (2) The thermometer and the knife used should be made not only clean but sterile each time after using in one sample before placing them in another.

Gerber's fermentation test.—This test consists in heating milk in tubes 6 hours at 104° to 106° F. and then observing the odor, appearance, taste, etc., for abnormal qualities. The milk is heated a second time for 6 hours at 104° to 106° F. Any abnormal coagulation of the milk is noticed, such as holes due to gas. Gerber states that milk coagulating in less than 12 hours is abnormal, due either to the abnormal character of the milk itself when drawn or to improper care after being drawn. Milk that does not curdle within 24 to 48 hours is open to the suspicion of containing preservatives and should be examined for such substances.

METHODS OF TESTING FOR ENZYMS IN MILK

Enzyms are chemical ferments; they have the power to produce changes in other substances without themselves undergoing appreciable change. Enzyms are the products of living cells; those in milk have their origin, in part, in the animal producing the milk and usually, in larger part, in the bacteria contained in the milk. Under this head we shall consider the following tests: (1) Reductase, (2) catalase, (3) distinction between heated and unheated milk.

Reductase test.—Ordinary normal milk possesses the power of decolorizing certain coloring-substances by reduction or removal of oxygen; this property appears to depend upon the presence of micro-organisms in milk since the larger the number of bacteria, the shorter the time required to produce decolorization. The coloring-substance that has been found especially useful in this test is a compound known as methylene-

blue; this does not combine with casein and is easily absorbed by living cells. A solution of this is prepared by putting a few grams of a solution of methylene-blue (using the zinc chloride double salt) into 20 cc. of alcohol and letting it stand at room temperature for 2 hours. Of this saturated solution take 5 cc. and mix it with 195 cc. of distilled water.

To perform the Barthel form of the test, add 1 cc. of the dilute methylene-blue solution to 20 cc. of milk and put the mixture in a warm place (113° to 122° F.). If the blue color disappears within an hour, the milk is to be regarded as very bad from a sanitary point of view and wholly unfit for the use of infants. If the color disappears within 3 hours, the milk is classed as of second quality; milk which remains wholly unchanged after the lapse of 3 hours is to be regarded as good.

Another simple way of performing the test is to mix 25 cc. of milk and 6 drops of a solution of pure methylene-blue (1:4000) in a cylinder. After shaking, the cylinder is stoppered with a cotton plug and put in a water-bath at 104° F. If the color disappears in less than 15 minutes, the milk is condemned.

This test is used as a rough measure of the number of bacteria in milk, since the decoloration or reduction of methylene-blue in milk appears to be due wholly to the activity of micro-organisms. The decoloration takes place in 5 minutes or less when the number of bacteria exceeds 10 millions per cubic centimeter.

Jensen's "reduction-fermentation" test is a modification of the Barthel method, using only 0.5 cc. of methylene-blue solution (instead of 1 cc.) and heating at

100° to 104° F. This method is more sensitive, decolorization taking place more quickly. Milk in which the blue color disappears in 15 minutes is regarded as unfit for use. The samples of milk are allowed to remain at the same temperature for the fermentation test and, at the end of 24 hours, the conditions are observed as in connection with the Wisconsin fermentation test (p. 155). This method gives useful evidence in regard to the abundance of living organisms present as well as the kinds of organisms present.

Catalase test.—Normal fresh milk has the property of decomposing hydrogen peroxide into free oxygen gas and water. This is believed to be due in part to the presence of white blood corpuscles (leucocytes), which are always present in milk, and in part to the action of micro-organisms. Substances in milk having the power to decompose hydrogen peroxide are known under the general name of *catalase*. It increases with the age of milk and is present more abundantly in milk of diseased cows.

The amount of catalase in milk can be estimated by treating a certain amount of milk with a certain amount of hydrogen peroxide under given conditions and measuring the free oxygen that is given off. Several forms of apparatus have been devised for the purpose.

The test is performed as follows: In a small fermentation tube or other suitable apparatus, we mix 15 cc. of milk and 5 cc. of 1 per cent. hydrogen peroxide; then place the apparatus at a temperature of 77° to 86° F. The amount of gas formed at the end

of 2 hours is observed. Milk older than 2 to 6 hours giving 4 cc. of oxygen by this test is regarded as abnormal.

This test has been found useful in detecting abnormal conditions in the milk of individual cows. A high catalase content in fresh normal milk is a sign of diseased udder after the colostral period is over. Increase of catalase in milk several (6 to 12) hours old indicates bacterial activity and may be used as a test of the keeping power of milk.

Methods for testing heated milk.—It is often desirable to know whether milk has been heated or not. In the case of pasteurized milk, it is important to learn whether it has been heated sufficiently to be really pasteurized.

Several tests have been devised for distinguishing between heated and unheated milk. They are based on the following facts: Unheated milk contains enzyms which, in the presence of peroxides, such as hydrogen peroxide, set free oxygen and this oxygen produces marked coloration when certain compounds are present. These enzyms, when subjected to a temperature above 172° to 176° F., are so changed that they lose the power of setting free oxygen from a peroxide and therefore they produce little or no color in milk so heated. Several different substances have been used, giving rise to as many tests, of which we will describe the following: (1) Para-phenylene-diamine test, (2) Guaiac test, (3) Methylene-blue test.

Para-phenylene-diamine or Storch test.—Into a cup or test-tube one puts about 5 cc. of milk, then one drop of a 0.2 per cent. solution of hydrogen peroxide and

two drops of a 2 per cent. solution of para-phenylene-diamine hydrochloride. The mixture is well shaken. If the milk has not been heated at all or to a temperature not above 172° F., an intensely blue color appears. If, however, after half a minute a clear, grayish-blue color appears, the milk has been heated up to 175° F. or higher. The reaction is of sufficient delicacy to detect 10 per cent. of milk heated below 172° F. in a lot of milk pasteurized above this temperature.

The solution of para-phenylene-diamine hydrochloride does not keep longer than 2 months and a new preparation should be made.

The test can be applied to cream or to butter. Melt about 10 grams of butter in a cup or beaker, heating to 105° to 115° F., add 10 cc. of warm water, 2 drops of 0.3 per cent. hydrogen peroxide solution and several drops of para-phenylene-diamine solution. Pour the mixture into a cream-testing bottle, shake vigorously and whirl in centrifuge 1 minute. In the watery solution that separates from the fat, a blue color appears if the cream from which the butter was made was not pasteurized.

Guaiac or Arnold test for heated mik.—To a small amount of milk in a cup or test-tube are added 5 or 10 drops of guaiac tincture (preferably a 5 or 10 per cent. solution prepared by dissolving guaiac resin in acetone) and the mixture shaken. In case of milk heated to less than 176° F., a blue color appears after some minutes; if it has been heated above 176° F., no coloration appears. The precaution should always be taken to test the guaiac solution with unheated milk, because some solutions produce no coloration even in

such milk. This can be remedied by adding a few drops of hydrogen peroxide to the solution.

A modification of this test can be used: To 1 cc. of milk, one adds 1 cc. of a water solution of guaiacol and 1 drop of hydrogen peroxide solution (3 per cent.). In unheated milk a strong orange color appears, but not in case of milk previously heated to 176° F.

Methylene-blue or Schardinger's test.—The reagent used in this test is a mixture of 5 cc. of a saturated solution of methylene-blue, 5 cc. of formalin and 190 cc. of distilled water. The test is performed as follows: To 20 cc. of milk add 1 cc. of Schardinger's reagent, warm to 113° to 122° F. and observe the time it requires to lose the color completely. Ordinary normal milk is decolorized in about 10 minutes with this test.

The reaction depends upon a specific enzym in milk called aldehyde-reductase, which is more or less quickly destroyed at temperatures above 158° F., while with milk heated above 176° F. decolorization is complete. When milk is pasteurized either 2 minutes at 167° F. or about 15 minutes at 158° F. the color disappears in about 30 minutes with the test.

METHODS OF TESTING MILK FOR SUSPENDED DIRT

In making an examination of milk with reference to its sanitary condition, dirt in suspension or sediment should always be tested for. There are several satisfactory methods. It is sufficient for most purposes to get a rough idea of the amount of sediment. There are three general methods in use: (1) By filtra-

tion, (2) by centrifugal machine, (3) by ordinary settling.

Filtration test for dirt.—This can be carried out in a very simple form by packing a funnel with some absorbent cotton and pouring a pint of milk on this. Most of the dirt will collect on the top of the cotton if it is not packed too loose.

The Wisconsin experiment station (Bulletin 195) has made a special device (Lorenz sediment-tester) for the application of this principle, which furnishes a convenient and effective means for filtering or straining dirt from milk. The details of construction are shown in Fig. 40. In operating the test, a cotton disc is placed in the cap over the wire gauze and then fastened in place. A pint of milk is then poured into the cylinder or funnel (A). When the milk has run through the filter, the cotton disc is removed and placed on a piece of white, clean paper to dry. Then another disk can be inserted and another sample of milk tested and the operation repeated for any desired number of samples. When many samples are tested in rapid succession, a numbered cap should be provided for each test.

The rapidity of testing many lots of milk depends on (1) the temperature of the milk while filtering and (2) on the character of the cotton filtering-discs. The milk filters more rapidly if it is kept hot; the apparatus provides for this condition. The cotton discs should be made of absorbent cotton that is entirely free from starch or similar material. The discs should be about one-eighth inch thick and cut out to fit the cap and wire gauze. When properly made,

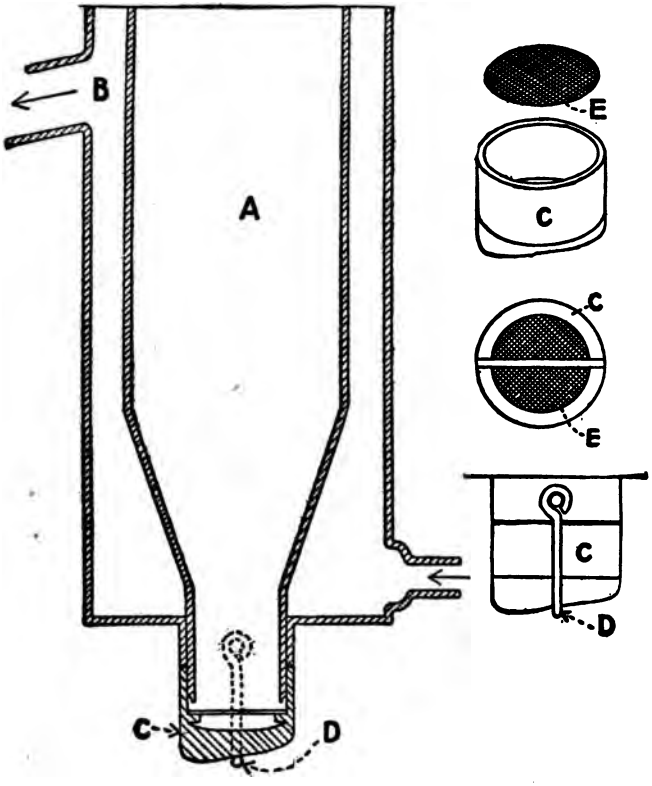


FIG 40—DETAILS OF CONSTRUCTION OF WISCONSIN OR LORENZ DIRT TESTER

The central cylinder *A*, through which the milk is poured is 2½ inches in diameter and 6 inches long, surrounded by a steam or hot water jacket and with a half-inch intervening space. The steam or hot water enters at the lower opening and overflows at *B*. The brass cap *C* slips over the bottom of the inner cylinder and is held in place by a clamp rod *D*. This cap contains a circle of wire gauze *E*, over which is placed the disc of absorbent cotton. The cap may be quickly removed by swinging the clamp rod *D* to one side and the dirty filter may be replaced by a clean one.

they allow the hot milk to filter rapidly but retain the dirt suspended in the milk.

Centrifugal test for dirt. —A small centrifugal machine that is made to run at a higher speed than the Babcock testers is used. A form of hand-centrifuge is shown in Fig. 41. Special graduated tubes (Fig. 42) are made to use in this. The milk to be tested is stirred thoroughly, the tube is filled to the highest mark, placed in the pocket of the centrifuge and whirled several minutes. The sediment col-

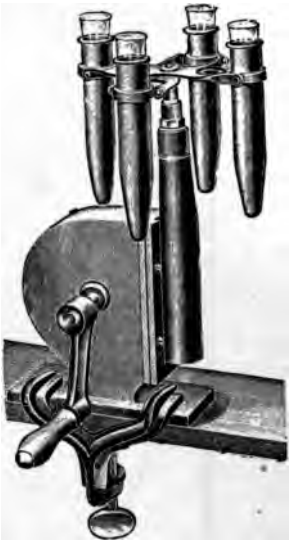


FIG. 41—HAND-CENTRIFUGE FOR SEDIMENTATION WORK

FIG. 42—TUBE FOR SEDIMENTATION WORK

FIG. 43—BAUSCH & LOMB ELECTRIC CENTRIFUGE
Speed, 1,000 revolutions per minute

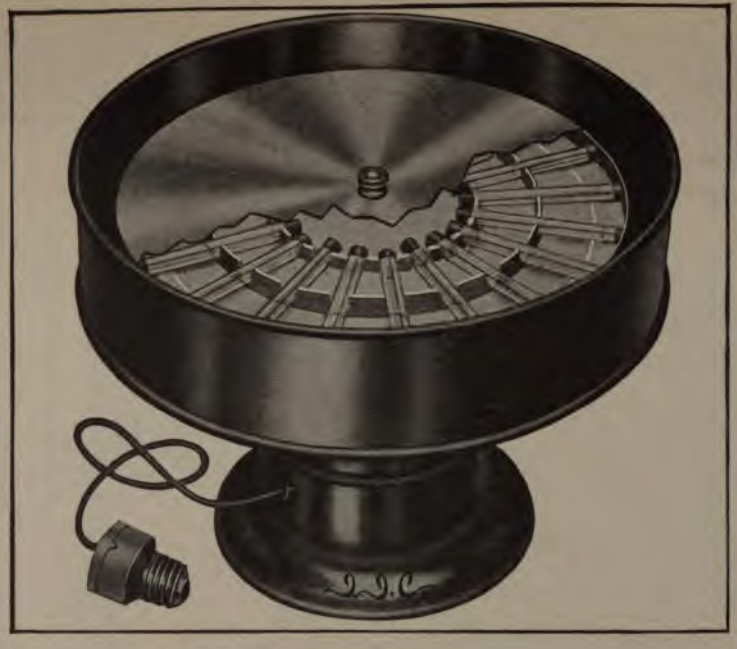


FIG. 44—INTERNATIONAL INSTRUMENT COMPANIES' ELECTRIC CENTRIFUGE FOR SEDIMENTATION WORK
Capable of 3,000 revolutions per minute

lects at the bottom and can be easily measured by reading the amount on the scale. In Fig. 43 is shown a Bausch and Lomb electric centrifuge. This company also furnishes hand-centrifuges capable of 3,000 to 8,000 revolutions per minute. Their centrifuges and tubes can be used also in testing for fat in milk by the Babcock method. In Fig. 44 is shown another form of electrical centrifuge which is very satisfactory for collecting sediments.

FIG. 45
GLASS FOR COLLECTING SEDIMENT IN MILK

Settling test for dirt.—A method less accurate, but fairly satisfactory in the absence of any better means, is to place about 4 ounces of milk in a test-glass (Fig. 45) and let it stand for one or two hours. The dirt collects in the bottom and its amount can be roughly estimated by the eye.

CHAPTER XII

Methods of Testing Milk by Rennet-Extract and Pepsin

In cheese-making it is necessary to have some means of finding out when the rennet-extract should be added to milk in order to secure the best results in the process. This is usually known as "testing the ripeness of milk." Two methods are in common use for this purpose: (1) The Monrad test and (2) the Marschall test.

THE MONRAD TEST

This test is based upon the amount of time required for a definite quantity of milk at a given tem-

FIG. 46—MONRAD RENNET-TEST

perature to become coagulated by a fixed quantity of rennet.

The pieces of apparatus (Fig. 46) required are the following: (1) A tin cylinder for measuring milk, holding, when full, 160 cc., (2) a 5 cc. pipette, (3) a

50 cc. glass flask, (4) a thermometer, and (5) a half-pint tin basin.

In testing the ripeness of milk by means of rennet-extract, one first prepares a dilute solution of the rennet, as follows: One measures with the small pipette 5 cc. of rennet-extract into the 50 cc. flask. The pipette is then rinsed twice with water by sucking it full of cold, clean water to the mark, the rinsings also being run into the 50 cc. flask. The flask is then filled with water to the 50 cc. mark, and the contents are well mixed by shaking. The next step is to fill the tin cylinder with the well-mixed milk to be tested and this is emptied into the half-pint basin. The milk must be at the temperature at which one adds the rennet in cheese-making, which is generally about 85° or 86° F. To the milk at the desired temperature, one adds 5 cc. of the diluted rennet solution, mixes it through the milk quickly, using the thermometer as a stirrer. The exact time when the rennet-extract is added to the milk is noted by the second-hand of a watch and then again when the milk has coagulated; the number of seconds required to coagulate the milk is recorded. The exact point of coagulation can be seen more sharply by scattering a few particles of charcoal (as the blackened end of a partly burned match) on the surface of the milk, and then with the thermometer starting the surface into motion around the dish. The black particles stop the instant the milk coagulates. By using a stop-watch, great accuracy and delicacy can be attained. Care should be taken to keep the temperature of the milk at 85° or 86° F., testing frequently with the thermometer; and,

in case the temperature drops, it can be raised by placing the basein of milk in warm water. In ordinary cheddar cheese-making, milk is ready for the addition of rennet when it coagulates in 30 to 60 seconds under the foregoing conditions.

THE MARSCHALL TEST

In this test the same general procedure is followed as in the Monrad test, but the rate of coagulation is observed in a different way. The following pieces of apparatus (Fig. 46a) are used: (a) A testing cup or basin, of about a pint capacity, for holding the milk to be tested. On the inside wall of this cup there are graduated spaces beginning with zero at the top and going by half-divisions to 7 near the bottom of the cup, while in the bottom of the cup is a metal tube with a very small bore.

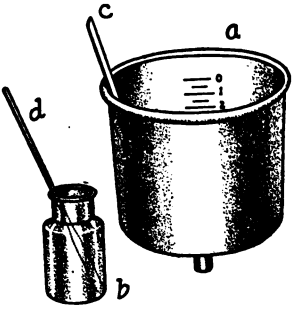


FIG. 46a
MARSCHALL RENNET-TEST

(b) An ounce bottle with a mark on it to indicate 20 cc. (c) A spatula for stirring the milk. (d) A 1 cc. pipette.

The operation of conducting this test is as follows: Measure with the pipette 1 cc. of the rennet-extract used and empty it into the ounce bottle, previously half filled with clean cold water. Rinse the pipette two or three times by drawing water into it from the

bottle and allowing it to run back into the bottle. Mix well by shaking. Then place the milk to be tested in the test-cup, setting it in a level position and allowing the milk to run out at the bottom. Taking the bottle of diluted rennet in one hand and the spatula in the other, watch the level of the milk in the cup. The moment the upper surface of the milk drops to the zero mark, pour the diluted rennet into the milk and stir well. Then leave it alone. When the milk coagulates, it stops running through the metal tube. From the graduated scale, read the number of spaces uncovered on the inside of the cup, showing how many divisions of milk have run out. The more slowly the milk coagulates, the larger the amount that runs out; the more quickly the milk coagulates, the smaller the amount that runs out and the fewer spaces there are uncovered. When about 2½ spaces are uncovered, the milk is ready for addition of rennet. The temperature must be watched, being tested at the start and finish, especially in a cold room.

In the Marschall test, as originally devised, there were some objectionable features. Formerly, glass tubing was used in the bottom of the cup and it was found that the size of the bore of tubing unavoidably varied in different cups. This made it impossible to compare the results of one cup with those of another, unless they were proved by actual testing to be alike. This difficulty has been overcome by dispensing with the use of glass tubing and substituting in its place aluminum tubing with the hole drilled to uniform exactness. One difficulty connected with the use of the Marschall test is that a little speck of dirt quickly

clogs the tube and, therefore, special pains must be taken to keep it open. For ordinary work the Marschall test is convenient but it is not capable of as great delicacy as is the Monrad test.

METHOD OF TESTING RENNET-EXTRACTS

Rennet-extract is prepared by soaking calves' stomachs in dilute brine. This treatment dissolves from the mucous membrane the enzym or chemical ferment that has the property of coagulating milk-casein, a property upon which the process of cheese-making is dependent. The ferment contained in rennet-extracts appears to be the same as pepsin in regard to its action upon milk casein. Different brands of rennet-extract vary somewhat in their strength, that is, the rapidity and completeness with which they coagulate milk when used in the same amount. It is, therefore, important to have a means of testing their strength, in order that their value may be definitely known and that cheese-makers may be able to know in advance of using how much they must use for the best results. The Monrad and Marschall tests are available for this purpose.

In order to test the comparative strength of different rennet-extracts, one treats different portions of the same milk with the different extracts to be tested. In all other respects, the details of the methods previously given are followed. All conditions must be kept alike in the different tests. The strength of the rennet-extracts is shown by the rapidity with which the milk is coagulated; the stronger the rennet, the less the time of coagulation.

METHOD OF TESTING PEPSIN

Pepsin is beginning to be used in cheese-making as a substitute for rennet-extract. Vivian has worked out the important details. The scale-pepsin, of strength known as 1-3,000, prepared from stomachs of sheep, is recommended. It may be used at the rate of 5 grams for 1,000 pounds of milk. In testing scale-pepsin by the rennet test, one can dissolve the scale-pepsin at the rate of 5 grams in 4 ounces of water and use this solution exactly like a rennet-extract with milk. It should be tested in comparison with a sample of rennet-extract whose use in cheese-making has been tested, the test being made on different portions of the same milk.

TESTING THE AGE OF MILK BY RENNET-TEST

The age of milks and the care with which they have been kept can also be tested in a comparative way by the rennet-test, since with the same rennet-extract or pepsin solution different milks generally coagulate more rapidly in proportion to the amount of acid contained in them, especially if the amount of lactic acid is considerable.

CHAPTER XIII

Methods of Testing Specific Gravity and Solids of Milk by the Lactometer

The specific gravity of milk may furnish important information, which becomes of special value when taken in connection with the amount of fat present. Thus, with the data furnished by the specific gravity and the per cent. of fat, we can easily calculate the amount of solids in milk and the amount of solids-not-fat.

THE SPECIFIC GRAVITY OF MILK

Definition of specific gravity.—By the specific gravity of milk, we mean the weight of a given bulk or volume of milk as compared with the weight of an equal volume of water at the same temperature. To illustrate, suppose we have a vat which, when just full of water, contains exactly 1,000 pounds of water at 60° F. Now, if we fill such a vat full of milk of average composition at the same temperature, this amount of milk weighs 1,032 pounds. This is so because the milk contains, in addition to the water in it, several solid substances heavier than water. In this illustration we express the relation or ratio of the equal volumes of water and milk by dividing 1,032 by 1,000; the result, 1.032, is the specific gravity of the milk.

Variation in specific gravity of milk.—Since the specific gravity of milk largely depends upon the amount of solids in it heavier than water, the specific gravity should vary, since we know that the amount of solids in milk varies considerably. And so we find the specific gravity of some milks below 1.030 and of some others above 1.035; but most normal milks from herds of cows have specific gravities lying between 1.030 and 1.034.

The solids of milk heavier than water are casein, albumin and milk-sugar. They constitute the solids-not-fat of milk and have a specific gravity of about 1.500.

Effect of milk-fat on specific gravity of milk.—Milk-fat is lighter than water, its specific gravity being about 0.900 compared with that of water as 1.000. Therefore, an increase of fat in milk, relative to the other solids, lowers the specific gravity of milk. Thus, by adding cream to normal milk, we can make its specific gravity lower than that of normal milk. On the other hand, by removing fat from milk, we increase the specific gravity, because we remove what is lighter, and leave what is heavier, than water.

Effect of adding water and other substances to milk.—Water being lighter than milk, the specific gravity of milk is lowered by addition of water. Therefore, it is easily possible by removing cream from normal milk to increase the specific gravity and then, by adding water, to decrease the specific gravity again to that of normal milk. The addition of sugar, salt or any similar substance to milk increases the specific gravity. Since water has been the most common adul-

terant of milk, it was formerly thought that such adulteration could readily be detected by ascertaining the specific gravity; but the results of using the specific gravity may be very misleading, when considered without reference to any other factor.

INFLUENCE OF TEMPERATURE ON SPECIFIC GRAVITY

Most liquids expand when heated and contract when cooled. A vessel full of milk or water at 40° F. will overflow when heated considerably higher, that is, will hold less of the fluid, and so the same volume weighs less at higher than at lower temperatures. From this it is readily seen that the specific gravity of a liquid like water or milk grows less when its temperature increases. On the other hand, a vessel full of water at 200° F. is not full when cooled to 40° F. The same weight of water occupies less volume and its specific gravity is higher. Decrease of temperature increases the specific gravity of liquids. It is therefore necessary in measuring the specific gravities of different liquids to have the measurements made at the same temperature, if they are to be comparable. The temperature commonly used is 60° F.

METHOD OF TESTING THE SPECIFIC GRAVITY OF LIQUIDS

The specific gravity of liquids is readily measured by an instrument known as a hydrometer. The use of such an instrument is based on the fact that, when a solid body floats in a liquid, it displaces an amount of liquid equal in weight to the weight of the floating

body. Thus it sinks deeper in a light liquid than in a heavy one, because it takes a larger volume of the light liquid to equal the weight of the floating body. Such an instrument is graduated as the result of extensive experiments, so that the specific gravity of the liquid in which the hydrometer is placed can be read at the point where the scale is even with the upper surface of the liquid. A hydrometer is correct only for the temperature used in standardizing it. When a hydrometer has a scale specially adapted to the limits of the specific gravity of milk, it is called a *lactometer*. Of the various lactometers made, only two are sufficiently used to deserve attention: (1) The Quevenne, and (2) the New York Board of Health, lactometers.

FIG. 47 QUEVENNE LACTOMETER

THE QUEVENNE LACTOMETER

Description.—This instrument (Fig. 48) is a hydrometer the scale of which is divided into 25 equal parts, going from 15 to 40. Each division is called a degree, and every fifth degree is numbered on the scale. The point marked 15 corresponds to the point marked specific gravity 1.015 on an ordinary hydrometer, and is the point to which it will sink when placed in liquids whose specific gravity is 1.015. The 40 degree mark on the Quevenne lactometer corresponds to the specific gravity 1.040 mark on a hydrometer. The relation between specific grav-

ity and the scale of the Quevenne lactometer is shown as follows:

SPECIFIC GRAVITY	*Reading of Quevenne lactometer*
1.015	15
1.020	20
1.025	25
1.030	30
1.035, etc.	35, etc

Corrections for temperature.—The Quevenne lactometer is graduated to give correct results at 60° F. When it is used in milk, the milk should be at 60° F., or, if at some temperature above or below 60° F., a correction of the lactometer reading must be made. This correction can be closely made by adding to the lactometer reading .1 for each degree above 60° F., or by subtracting .1 for each degree below 60° F. For more exact corrections, consult table on the following page.

The Quevenne lactometer should carry a thermometer, the scale of which is placed for convenience above the lactometer scale.

Process of using Quevenne lactometer.—The sample of milk to be tested for specific gravity is brought to a temperature between 50° and 70° F. For convenience the milk is placed in a cylinder (Fig. 49), which is nearly filled. The lactometer is carefully lowered into the milk until it floats and is allowed to remain half a minute or more. Then one reads and records (1) the point at which the lactometer scale comes in contact with the upper surface of the milk; and (2) the temperature. The lactometer reading is

TABLE I. CORRECTIONS FOR SPECIFIC GRAVITY OF MILK FOR VARIATIONS IN TEMPERATURE

DEGREES OF LACTOMETER	TEMPERATURE OF MILK																		
	51° F.	52° F.	53° F.	54° F.	55° F.	56° F.	57° F.	58° F.	59° F.	60° F.	61° F.	62° F.	63° F.	64° F.	65° F.	66° F.	67° F.	68° F.	69° F.	70° F.
	Lact. deg.	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*	*Lact. deg.*
25	24.2	24.3	24.4	24.5	24.6	24.6	24.7	24.8	24.9	25	25.1	25.2	25.3	25.4	25.5	25.6	25.7	25.9	26.0	26.1
26	25.2	25.2	25.3	25.4	25.5	25.6	25.7	25.8	25.9	26	26.1	26.2	26.3	26.5	26.6	26.7	26.8	27.0	27.1	27.2
27	26.2	26.2	26.3	26.4	26.5	26.6	26.7	26.8	26.9	27	27.1	27.3	27.4	27.5	27.6	27.7	27.8	28.0	28.1	28.2
28	27 1	27.2	27.3	27.4	27.5	27.6	27.7	27.8	27.9	28	28.1	28.3	28.4	28.5	28.6	28.7	28.8	29.0	29.1	29.2
29	28.1	28.2	28.3	28.4	28.5	28.6	28.7	28.8	28.9	29	29.1	29.3	29.4	29.5	29.6	29.8	29.9	30.1	30.2	30.3
30	29.1	29.1	29.2	29.3	29.4	29.6	29.7	29.8	29.9	30	30.1	30.3	30.4	30.5	30.7	30.8	30.9	31.1	31.2	31.3
31	30.0	30.1	30.2	30.3	30.4	30.5	30.6	30.8	30.9	31	31.2	31.3	31.4	31.5	31.7	31.8	31.9	32.0	32.2	32.4
32	31 0	31.1	31.2	31.3	31.4	31.5	31.6	31.7	31.9	32	32.2	32.3	32.5	32.6	32.7	32.9	33.0	33.2	33.3	33.4
33	31.9	32.0	32.1	32.3	32.4	32.5	32.6	32.7	32.9	33	33.2	33.3	33.5	33.6	33.8	33.9	34.0	34.2	34.3	34.5
34	32.9	33.0	33.1	33.2	33.3	33.5	33.6	33.7	32.9	34	34.2	34.3	34.5	34.6	34.8	34.9	35.0	35.2	35.3	35.5
35	33.8	33.9	34.0	34.2	34.3	34.5	34.6	34.7	34.9	35	35.2	35.3	35.5	35.6	35.8	35.9	36.1	36.2	36.4	36.5

then corrected, if the temperature is above or below 60° F. For example, the lactometer settles in milk, which is at a temperature of 65° F., to the point marked 29. Adding to the reading for correction .1 for each degree above 60° F., which in this case is .5, the reading becomes 29.5. This means that the specific gravity is 1.0295. If the temperature of the milk were 55° F., the correction is subtracted and the reading becomes 28.5, equal to specific gravity 1.0285.

THE NEW YORK BOARD OF HEALTH LACTOMETER

Description.—This lactometer has been in common use among milk-inspectors in the eastern and middle states. Its scale is quite different from that of the Quevenne lactometer, since it is divided into 120 equal parts. Beginning at the top of the instrument, the zero point on the scale is the point to which the lactometer sinks in water; and the point is marked 100 to which it settles in milk of specific gravity 1,029 at 60° F. (Quevenne reading, 29), the lowest limit supposed to belong to normal milk. The distance between the zero and 100 points is divided into 100 equal parts and the scale is then prolonged beyond the 100 mark for 20 divisions to 120. The instrument is used in the same way as the Quevenne lactometer in testing milk.

FIG. 48
CYLINDER FOR LACTOMETER

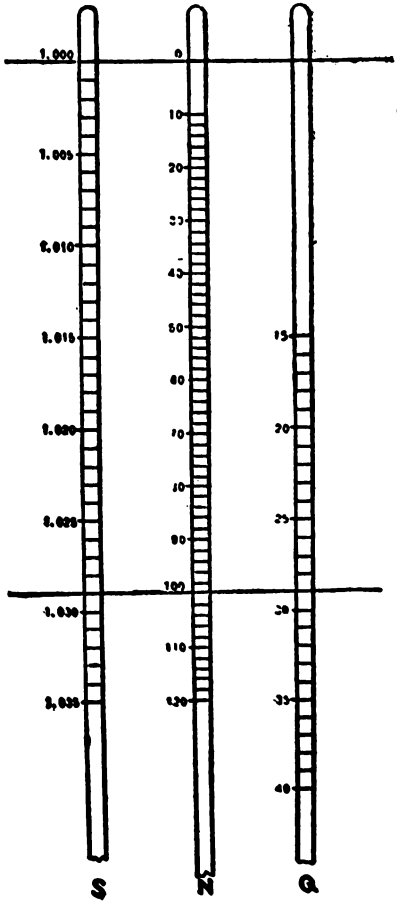


FIG. 49—COMPARISON OF DIFFERENT SPECIFIC GRAVITY SCALES

S is specific gravity scale; *N* is New York Board of Health lactometer; *Q* is Quevenne lactometer.

Comparison of the two lactometer scales.—In comparing the scales of the Quevenne and Board of Health lactometers, the following points will make clear their relations: (1) The zero point on both instruments indicates the specific gravity of water, that is, 1.000. (2) On the B. of H. lactometer, the 100 divisions or degrees from 0 to 100 correspond to 29 divisions on the Quevenne. Therefore one degree on the B. of H. lactometer corresponds to .29 degree on the Quevenne. To convert the B. of H. lactometer reading into that of the Quevenne, multiply the reading of the former by .29. The relation of the specific gravity scale of a hydrometer

to the scales of the Quevenne and B. of H. lactometer is shown in Fig. 50.

TABLE II.—DEGREES ON QUEVENNE LACTOMETER CORRESPONDING TO DEGREES ON NEW YORK BOARD OF HEALTH LACTOMETER

BOARD OF HEALTH	QUEVENNE	BOARD OF HEALTH	QUEVENNE	BOARD OF HEALTH	QUEVENNE
Degrees	*Degrees*	*Degrees*	*Degrees*	*Degrees*	*Degrees*
60	17.4	81	23.5	101	29.3
61	17.7	82	23.8	102	29.6
62	18.0	83	24.1	103	29.9
63	18.3	84	24.4	104	30.2
64	18.6	85	24.6	105	30.5
65	18.8	86	24.9	106	30.7
66	19.1	87	25.2	107	31.0
67	19.4	88	25.5	108	31.3
68	19.7	89	25.8	109	31.6
69	20.0	90	26.1	110	31.9
70	20.3	91	26.4	111	32.2
71	20.6	92	26.7	112	32.5
72	20.9	93	27.0	113	32.8
73	21.2	94	27.3	114	33.1
74	21.5	95	27.6	115	33.4
75	21.7	96	27.8	116	33.6
76	22.0	97	28.1	117	33.9
77	22.3	98	28.4	118	34.2
78	22.6	99	28.7	119	34.5
79	22.9	100	29.0	120	34.8
80	23.2	....	....	....	....

Corrections for temperature.—In using the B. of H. lactometer, correction is made for temperatures above or below 60° F. For each degree of temperature of milk above 60° F., add .3 to the lactometer reading, and for each degree below 60° F. subtract .3 from the reading.

PRECAUTIONS IN TESTING SPECIFIC GRAVITY OF MILK

1. Milk should, for best results, not be examined until 1 to 2 hours or more after milking, since the specific gravity of milk is lower for a while after being drawn than it is later, due chiefly to the presence of gases.

2. The sample of milk must be completely mixed.

3. The lactometer must be kept clean.

4. In milk which has been preserved by potassium bichromate, the specific gravity is about one degree higher than in the normal milk, in case the usual amount of bichromate has been added. (See p. 30).

VALUE OF LACTOMETER IN DETECTING ADULTERATED MILK

The value of the lactometer in detecting adulterated, especially watered, milk was formerly overestimated. Taken alone, the results given by the lactometer may be thoroughly unreliable and misleading. It has come to be quite generally recognized that the proper use of the lactometer in milk inspection is largely to indicate whether a sample is suspicious and to furnish a guide as to whether it is necessary to take a sample for further detailed investigation by chemical anal-

ysis. As already stated, a milk which is both skimmed and watered may appear to be entirely normal by the lactometer.

METHOD OF TESTING MILK FOR SOLIDS BY LACTOMETER

As the result of extended studies of the relations existing between the specific gravity of milk, milk-fat and milk-solids, rules have been formulated by means of which it is possible to calculate with a close degree of approximation the total solids of milk, when one knows the percentage of fat and the (Quevenne) lactometer reading.

Babcock's formulas for solids and solids-not-fat.—The following formulas were devised by Dr. Babcock:

(1) *Formula for determining solids-not-fat.*—Solids-not-fat=¼L+.2f, in which L is the reading of the Quevenne lactometer and f is the per cent. of fat in the milk.

(2) *Formula for determining solids in milk.*—Total solids=¼L+1.2f.

These formulas can be expressed in the form of rules as follows:

Rule 1.—To find the per cent. of solids-not-fat in milk, divide the reading of the Quevenne lactometer by 4, and to the result add the per cent. of fat in the milk multiplied by .2.

Rule 2.—To find the per cent. of solids in milk, divide the Quevenne lactometer reading by 4, and to the result add the per cent. of fat multiplied by 1.2.

Examples:—A milk containing 4 per cent. of fat

FIG. 50
RICHMOND'S
SLIDE-RULE

shows a lactometer reading of 32. What is the per cent. (a) of solids-not-fat, (b) of total solids?

(a) The lactometer reading (32), divided by 4, equals 8. The per cent. of fat (4), multiplied by .2, equals .8. Adding 8 and .8, we obtain 8.8 as the per cent. of solids-not-fat.

b) The per cent. of total solids in the milk is 12.8 per cent.; for the lactometer reading, divided by 4, equals 8, the per cent. of fat (4) multiplied by 1.2 equals 4.8, and 8 plus 4.8 equals 12.8.

Richmond's slide-rule for calculating solids.—Instead of going through the details of calculation to estimate solids in milk, Richmond uses a slide-rule which is a clever mechanical calculating device. (Fig. 51). The results obtained in this manner agree closely with those given by Babcock's formulas. The method of using the slide-rule is as follows: Determine (1) the Quevenne lactometer reading, (2) the temperature of the milk, and (3) the per cent. of fat in the milk. Then set the central slide of the rule so that the observed lactometer reading is opposite the 60 degree (temperature) mark. The true lactometer reading is found opposite the line indicating the observed temperature of the milk. Having thus corrected the lactometer reading for temperatures

other than 60° F., next set the arrow on the sliding portion of the rule opposite the per cent. of fat found in the milk and read the total solids contained in the milk corresponding with the corrected lactometer reading or specific gravity.

To illustrate, suppose the lactometer reading of a sample of milk at 70° F. is 30 and the per cent. of fat is 4. To correct for temperature and find what the lactometer reading would be at 60° F., the lactometer reading (30) is placed opposite the little arrow at 60 on the temperature scale. Then, looking at the point of temperature 70, we find opposite this point 31.3, which is the corrected or true reading. Next, we place the arrow opposite the 4 per cent. mark, as the milk contains 4 per cent. of fat, and then notice where the point 31.3 (specific gravity), comes in contact with the solids scale. It corresponds closely to 12.8, which is the per cent. of total solids in the sample of milk examined. Some practice with this slide-rule enables one to work rapidly.

Specific gravity of milk-solids.—The following rule has been proposed by Fleischmann for calculating the specific gravity of milk-solids: Multiply the specific gravity of the milk by 100, from the result subtract 100 and divide this result by the specific gravity of the milk. Subtract the last result from the per cent. of total solids in the milk and then divide by this result the per cent of total solids of the milk. This may also be expressed by the following formula:

$$\text{Sp. gr. milk-solids} = \frac{\text{milk-solids}}{\text{milk-solids} - \frac{(100 \times \text{sp. gr.}) - 100}{\text{sp. gr.}}}$$

Example: A sample of milk contains 12.5 per cent. of solids and has a specific gravity of 1.031; —what is the specific gravity of the milk-solids?

$$\frac{100 \times 1.031 - 100}{1.031} = 3.006; \quad 12.5 - 3.006 = 9.494; \quad \frac{12.5}{9.494} = 1.32$$

This calculation may assist in determining whether a sample of suspected milk has been adulterated. The variations of the specific gravity of milk-solids is slight, ranging between 1.25 and 1.34. Milks richer in fat have solids of lower specific gravity. The specific gravity of milk-solids is not changed by watering milk, but is increased by removing fat or by addition of skimmed milk. Hence, milk whose solids have a specific gravity above 1.34 is suspected of being skimmed, while a specific gravity above 1.40 is regarded as clear evidence of skimming.

CHAPTER XIV

Methods of Testing Milk for Casein

Until quite recently there have not been available simple methods for the determination of casein in milk. Two methods are now in use: one of them resembles somewhat the process used in determining acidity in milk, employing the principle of neutralization and titration with alkali; while the other precipitates the casein and collects it by centrifugal force in a graduated tube.

VOLUMETRIC TEST FOR CASEIN

This method was worked out at the New York State experiment station (Technical Bulletin No. 10) by Van Slyke and Bosworth. In outline, the method is as follows: Into a 200 cc. flask measure 17.5 cc. (18 grams) of milk, add about 80 cc. of water and 1 cc. of phenolphthalein, after which run in a solution of sodium hydroxide (caustic soda) until the mixture is neutral. Standardized acetic acid is then added until the casein is completely precipitated, the volume of the mixture is made up to 200 cc. by addition of water and the whole is then filtered. Into 100 cc. of the clear

filtrate, standardized sodium hydroxide solution is run until neutral. The solutions are so standardized that 1 cc. is equivalent to 1 per cent. of casein in the milk examined. Therefore, the number of cubic centimeters of standard acid used, divided by 2, less the amount of standard alkali used in the final titration gives the percentage of casein in milk. The operation usually requires 12 to 15 minutes when apparatus and solutions are at hand in convenient form ready for use; several determinations can be carried on at the same time to advantage.

Apparatus.—Most of the apparatus is such as is in common use in dairy work in acidity testing (p. 131).

(1) Two 50-cc. *burettes* accurately graduated to one-twentieth cubic centimeters. Automatic burette-fillers save much time.

(2) *Flasks,* volumetric, holding 200 cc. and accurately marked. For greatest convenience, flasks having necks 4½ to 5 inches long and ¾ inches inside diameter are preferable.

(3) *Pipette* (Babcock-test form), accurately graduated to deliver 17.5 cc. (18 grams) of milk.

(4) *Pipette* graduated to deliver 100 cc.

(5) *Pipette* graduated to deliver about 1 cc. and provided with a rubber bulb (so-called dropper).

(6) *Cups,* plain white, holding 200 cc. or more.

(7) *Funnels,* glass or granite-ironware, 3 to 4 inches in diameter.

(8) *Filter-papers* cut round, 6 to 7 inches in diameter; or filters of fine linen cut to proper size and shape, which can be used repeatedly, being thoroughly washed each time.

(9) *Measuring-cylinders,* accurately graduated and holding 1000 cc.

Solution.—Three solutions are used: (1) Sodium hydroxide, (2) acetic acid and (3) phenolphthalein.

(1) *Sodium hydroxide* (caustic soda). This solution is most conveniently prepared by purchasing from a reliable chemical-supply house the ***standard normal*** solution and then diluting exactly 100 cc. of this to 1260 cc. (or 79.5 cc. to 1000 cc.), using pure distilled water, if possible, or else as pure rain water as is obtainable. Alkali solutions must be kept in tightly-stopperel bottles (p. 138). "Alkaline tablets" (p. 142) cannot be used for the casein test.

(2) *Acetic acid.* This solution is so made that 1 cc. will neutralize 1 cc. of the alkali solution. The simplest method of preparation is to purchase a ***standard normal*** solution and dilute 100 cc. to 1260 cc. (or 79.5 cc. to 1000 cc.). Add a small amount of dry mercuric chloride (corrosive sublimate) to prevent fermentation, and keep the solution in tightly-stoppered bottles.

(3) *Phenolphthalein.* Dissolve 1 gram of the dry powder in 100 cc. of 50 per cent. alcohol, adding one or more drops of dilute alkali until the solution is very slightly pinkish in color.

Performing the test.—For convenience, the process can be divided into six stages or operations: (1) Measuring and diluting sample of milk, (2) neutralizing the milk, (3) precipitation of casein, (4) filtration of casein, (5) titration with alkali, (6) calculation of results.

(1) *Measuring and diluting sample of milk.* The milk to be tested is well mixed and a 17.6 cc. pipette

filled to the mark and the milk run into a 200-cc. flask. To this is added about 80 cc. of pure, soft water, preferably distilled.

(2) *Neutralizing the milk.* To the diluted milk add 1 cc. of phenolphthalein solution and then run into it the alkali solution from the burette, in small portions, shaking vigorously after each addition, until a faintly but distinctly pinkish shade of color remains even after considerable agitation. *Marked excess of alkali must be avoided.* In this connection, the preparation and use of a color-standard are desirable.

(a) Preparation of a color-standard.—More satisfactory results in neutralizing can be attained by preparing a color-standard for comparsion, as follows: About 20 cc. of fresh skim-milk and 80 cc. of water are put into a 200-cc. flask and a small amount of corrosive sublimate added to prevent souring. A few drops of ordinary carmine ink are considerably diluted with water and this is carefully added, a few drops at a time, to the diluted skim-milk until a faint but distinct pinkish coloration appears. This can be more readily and accurately perceived by placing beside the flask another flask half full of uncolored diluted skim-milk. The coloration must be as slight as possible and yet be appreciably distinct when compared with uncolored milk. After the color-standard has been prepared, the flask is stoppered. It is well to keep this standard in a dark place when not in use. With some carmine colors, the pinkish shade in the milk deepens on standing especially when exposed to light, and with others it may fade. If at any time a deeper shade is observed, the proper shade can be reproduced by slight dilution

with skim-milk; in case of fading, the addition of one or more drops of carmine ink is needed. Skim-milk is used to avoid the presence of fat which, in case of

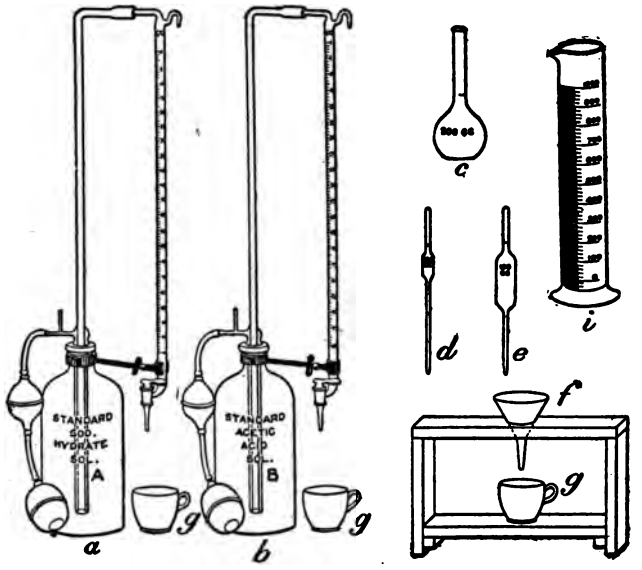


FIG 51—APPARATUS AND REAGENTS REQUIRED IN THE NEW YORK STATE STATION VOLUMETRIC CASEIN TEST

whole milk, separates on standing, adheres to the sides of the flask and obscures the color.

(b) Use of color-standard.—In neutralizing a sample of milk, the color-standard is placed beside the sample under examination for constant comparison after each addition of alkali. The flasks should be placed on a white surface and in a good light. In fresh milks, it is usually found that 3 or 4 cc. of alkali is

sufficient to make the milk neutral. One can usually add 2 or 3 cc. of alkali at the start and then add it in smaller portions, until the milk begins to show signs of neutrality, after which the alkali is added a drop at a time.

(3) *Precipitation of casein.* This step of the process needs to be considered in relation to the addition of acid and temperature.

(a) Addition of acid.—Into the neutralized sample of diluted milk, which should be at a temperature of 60° to 80° F., one now runs from a burette some of the standardized acetic acid, adding the acid approximately in 5 cc. portions and agitating vigorously for a few seconds after each addition. It is usually safe to add about 25 cc. of acid before examining the milk to see if the casein separates in the form of white flakes. After adding 20 to 25 cc. and shaking, the mixture is allowed to come to rest. If enough acid has been added, the casein separates promptly in large, white flakes, and, on standing a short time, the liquid above the settled casein appears clear and not at all milky. If the addition of 25 cc. of acid is insufficient to separate the casein properly, add 1 cc. more of acid and shake; continue the addition of acid, 1 cc. at a time, until the casein is observed to separate promptly and completely on standing at rest a short time. The number of cubic centimeters of acid used to effect precipitation is noted and *this result is recorded as A.*

(b) Influence of temperature.—For convenience of work and uniformity of results, the temperature of the mixture at the time of the addition of acid may be between 60° and 80° F. Under these conditions, many

milks give satisfactory results with 30 cc. of acid. In case of milk containing 3.5 to 4 per cent. of casein, 35 to 45 cc. of acid may be needed. The amount of acid may be 3 to 5 cc. in excess of that required to effect complete precipitation without affecting appreciably the accuracy of the results, provided the temperature of the mixture is below 80° F. In working at temperatures under 65° F., the casein separates more slowly or requires more acid to separate promptly; in such cases, it is well to use for dilution water that is at a temperature of 80° to 85° F.

(4) *Filtration of casein.* After the casein is completely precipitated, pure, soft water (preferably, distilled) is added until the 200 cc. is reached. The flask is then vigorously shaken 10 or 15 seconds, in order to make the distribution of acid through the mixture as uniform as possible. The contents of the flask are then poured on a dry filter and the filtrate caught in a cup. The funnels, filters and cups should all be dry before being used. It is well generally to allow the filtration to continue until practically all of the liquid has run into the cup. Two points deserve attention in this connection, (1) the rapidity of filtration and (2) the appearance of the filtrate.

(a) Rapidity of filtration.—The usual time of filtration should not exceed 3 to 5 minutes. The rapidity depends upon the temperature of precipitation and the completeness of the separation of casein. In general, the higher the temperature of the mixture when precipitated with acid, the more rapid should be the filtration, other conditions being uniform. In case of insufficient acid, the filtration is slower.

(b) Appearance of filtrate.—The filtrate should be quite clear, though this is not always a sure indication that the right amount of acid has been used. Sometimes the filtrate may be clear when not quite enough acid has been added, in which case the filtration is usually slow. In case of milks rich in fat, a slight turbidity may appear, due to fat-globules in the filtrate. The filtrate should be free from all signs of marked turbidity or anything like milkiness. If such a filtrate appears, a new sample of milk should be taken and the operation repeated from the beginning, more acid being used than before. With a little experience, especially under proper instruction, no difficulty should be found in recognizing quickly when the casein is separated so as to give satisfactory results.

(5) *Titration with alkali.* After filtration is completed, one measures 100 cc. of the filtrate with the pipette into a cup and then from the burette runs into this the standard alkali until a faint, but distinct, pink color remains clearly marked through the solution for half a minute or longer before beginning to fade. The number of cubic centimeters of alkali used is noted and *this result is recorded as B.*

The last portions of alkali must be added carefully, a drop at a time, agitating the mixture well after each addition. The exact neutral point is not perfectly sharp on account of the presence of phosphates, and the apppearance of the desired coloration is, therefore, not as sudden and pronounced as might be desired. With experience one should have no difficulty in getting within one drop of the correct amount of alkali. The chief precaution to be observed is to have the same

shade and duration of color every time. Thus one should not in one titration add alkali until a deep pink coloration appears, lasting for some minutes, and then in another, a coloration that disappears within 5 seconds.

(6) *Calculation of results.*—The method of obtaining the percentage of casein is very simple: Divide by 2 the number of cubic centimeters of acid used (A) and from the result subtract the number of cubic centimeters of alkali used (B) in neutralizing 100 cc. of filtrate; or, expressed more briefly, *divide A by 2 and from the result subtract B.* Expressed as a formula this becomes: (A÷2)—B=Per cent. of casein in milk.

Example: One uses 30 cc. (*A*) of acid in precipitating casein and 11.95 cc. (*B*) of alkali in neutralizing 100 cc. of filtrate (one-half of filtrate from the casein precipitate, corresponding to 9 grams of milk). Substituting 30 for *A* and 11.95 for *B* in the formula, we have (30÷2)—11.95=15—11.95=3.05 (per cent. of casein in milk).

Use of preservatives.—In making a casein determination by this method, it is desirable when possible to use milk not more than 24 hours old, which has been kept in a cool place. Milk which is sour or which coagulates on heating can not be used with satisfactory results. However, by adding to fresh milk powdered mercuric chloride (corrosive sublimate) in the approximate proportion of 1 part to 1,000 or 1,500 parts of milk, and then keeping the mixture at a temperature of 50° F. or lower, one can obtain satisfactory results with milk that had been kept 2 to 3 weeks. Milk thus treated should be shaken often enough to keep the fat well

incorporated in the body of the milk. The desired amount of mercuric chloride may be approximately measured by taking the quantity that will easily lie on the surface of a silver dime for one quart of milk or, more conveniently, the amount held by a 0.22-inch, pistol cartridge-shell ½ inch long, when loosely filled. A stiff wire soldered to such a shell makes it convenient to handle. Commercial mercuric chloride tablets containing color-matter can *not* be used.

Summary of Precautions.—Below we give in outline the special points to be observed with care in performing the operations of the test, assuming that the graduated glassware is accurate and the solutions of correct strength.

(1) *Preliminary neutralization.* In the neutralization of the sample of milk, excess of alkali must be avoided; this can be controlled by the use of a properly prepared color-standard.

(2) *Conditions of precipitation.* Before precipitating with acid, have the dilute, neutralized milk at a temperature between 60° and 80° F. Add enough acid to cause the casein to separate promptly in large flakes, leaving the supernatant liquid clear. Shake the mixture vigorously at intervals during the addition of acid; also after complete precipitation and again after dilution to the 200 cc. mark.

(3) *Filtration.* Allow most of the liquid to run through the filter before making the final titration with alkali.

(4) *Titration with alkali.* In titrating the filtrate with alkali, avoid an excess of alkali. Add the alkali solution cautiously until, after thorough agitation, a

faint but distinct pink color remains through the solution half a minute or longer. The same uniform shade and duration of pink color should be obtained as nearly as possible in all cases.

(5) *Acid milk.* Milk that is sour or that coagulates on heating should not be used.

(6) *Use of preservatives.* Milk treated, when fresh, with a small amount of powdered mercuric chloride and then kept in a cool place gives good results for two or three weeks.

CENTRIFUGAL TEST FOR CASEIN

The following method has been devised at the Wisconsin experiment station (Bulletin 156) by Hart:

Apparatus and Reagents.—(1) Testing-tubes with neck so graduated that each division represents 0.2 per cent. when a 5-cc. sample of milk is used. (2) Centrifuge of special form, run by hand, having a wheel 15 inches in diameter and geared to give a speed of 2000 revolutions a minute. (3) Pipette for measuring 5 cc. of milk. (4) Cylinder for measuring 2 cc. of chloroform. (5) Dilute acetic acid containing 0.25 per cent. prepared by diluting 10 cc. of glacial acetic acid to 100 cc. with water, and then diluting 25 cc. of this solution to 1000 cc. (6) Chloroform of the best quality.

Method of operating test.—In a testing-tube one puts 2 cc. of chloroform and on top of this 20 cc. of the dilute acid. Milk (65° to 75° F.) is then run in, after which the thumb is placed over the opening of the tube which is then inverted to bring the mixture into the barrel-shaped portion; then the whole is shaken with considerable vigor for 15 to 20 seconds, accurately

timed with watch under the eye. The tubes are then placed in the centrifuge within 20 minutes and whirled 7½ to 8 minutes at a speed of 2000 revolutions a minute. This must be done with such precision that the use of a metronome is recommended as important during the whirling. The whirling done, the tubes are removed and placed in an upright position in a rack and then read after 10 minutes or more. The end surfaces of the cylindrical mass of casein should be flat; the result in per cent. of casein is read directly on the scale. Fresh milk is desirable, but it is said that 7-day composite samples may be used by taking 1-ounce samples of milk daily, in a brown or amber-colored bottle, adding on the first and third days 1½ to 2 grains of bichromate (one-fourth ordinary tablet). This test demands more than ordinary exactness of manipulation.

CHAPTER XV

Methods of Testing Milk and Milk Products for Adulterations

Milk is commonly adulterated in one of the following ways: (1) By addition of water, (2) by removal of fat (skimming) or addition of skim-milk, (3) by addition of substances not normally found in milk, such as preservatives and coloring matter. All these forms of adulteration may occur in the same milk.

DETECTION OF ADDED WATER IN MILK

Since water in milk is the same chemical compound as the water found everywhere else, it is impossible to identify added water in milk by any direct test for special properties. The presence of added water in milk can be learned with certainty only by indirect means and even then not with certainty in all suspected cases. An examination of milk direct from the cow or herd, when this is possible, may settle the question of watering. The lactometer, while unreliable as a sure means of detecting added water in milk, may give a helpful suggestion, used as a preliminary test. Thus, if a milk shows a specific gravity under 1.028, it is open to the suspicion of being watered, and should then be carefully examined in other ways.

Most states fix legal standards for the per cent. of water, solids, fat, and solids-not-fat in milk, and any

milk falling below the fixed limit in composition is regarded as adulterated. Thus, a standard common to several states is 12 per cent. of solids and 3 per cent. of fat. This means also that such legal-standard milk must not contain more than 88 per cent. of water or less than 9 per cent. of solids-not-fat.

The relations of the different constituents of milk have been studied and formulas have been devised which enable one in an approximate way to tell how much water has been added to a sample of milk beyond the amount allowed by the standards. These formulas are based on the assumption that the limits fixed by the legal standard represent the lowest amounts of solids and fat found in normal milk, and they are correct only when the original milk contains the lowest percentages given in the legal standard.

In calculating the amount of added water in milk, the amount of solids-not-fat (total solids minus fat) is used as a basis. The procedure is as follows:

(1) Determine the per cent. of fat in the suspected sample.

(2) Take the lactometer (Quevenne) test.

(3) Determine the amount of solids-not-fat according to the formula, $\frac{1}{4}L+.2f$. (p. 137).

(4) Apply the following rule: Multiply the per cent. of solids-not-fat by 100 and divide the result by the legal standard for solids-not-fat. Subtract the last result from 100 and the result is the per cent. of added water in the sample of suspected milk. This rule is expressed in the form of the following formula:

$$\text{Per cent. of added water} = 100 - \frac{\text{per cent. of solids-not-fat} \times 100.}{\text{legal standard for solids-not-fat.}}$$

This formula gives only the amount of water added beyond the limit fixed by the legal standard and is correct only if the original milk contained the amount of solids-not-fat prescribed by the standard (usually 9 per cent.). Hence, in cases of watered milk, the calculated amount of water added is generally less than the real amount added.

Example: A milk is found to contain 3 per cent. of fat and to show a lactometer reading of 27. Applying the formula for finding the amount of solids-not-fat, the per cent. is 7.35. If the legal standard for solids-not-fat is 9, then the formula becomes

$$100-\frac{7.35\times 100}{9}=18.3,$$

the per cent. of added water that is contained in the milk, assuming that it contained 9 per cent. of solids-not-fat before being watered.

The following rule can also be used: Add together the lactometer reading and the per cent. of fat present in the milk, divide the sum by 36, multiply the result by 100 and subtract the last result from 100. Expressed as a formula, this becomes

$$\text{Per cent. of added water in milk}=100-\frac{\text{lactometer reading}+\text{per cent. of fat}}{36}\times 100.$$

An examination of the serum of milk by means of a refractometer gives, probably, the most reliable means of detecting added water in milk, but this method is available only for special workers. For its details see "Food Inspection and Analysis," by Leach, (p. 139).

DETECTION OF SKIMMED MILK

The percentage of fat in milk in relation to the other milk-solids is reduced either (1) by direct removal of fat through some process of skimming or (2) by the addition of separator skim-milk to normal milk. Milk containing less than 3 per cent. of fat is generally skimmed. Watering milk does not disturb the relations of the constituents of milk to one another, since it reduces the percentages of all uniformly, but the removal of fat does very seriously affect the amounts of the constituents in respect to their relative percentages. In skimming milk, the solid constituent most largely removed is fat, comparatively little casein, sugar, etc., being taken with the fat. The removal of fat therefore leaves the milk containing less fat but with most of its casein, sugar, etc., still remaining. In normal herd milk, containing over 3 per cent. of fat, the percentage of fat is rarely as low as the percentage of casein and albumin. In 5,500 analyses of samples of American milks, compiled by the author, with a fat content lying between 3 and 5 per cent., the fat averages 3.92 per cent., and the casein and albumin together, 3.20 per cent.; that is, for 1 part of casein and albumin there is an average of 1.225 parts of fat. In skimming such milk, the fat may be decreased to 1 per cent. or .1 per cent., but the remaining milk still contains about 3.20 per cent. of casein and albumin. Milk is open to the suspicion of being skimmed, when the percentage of fat falls below that of the casein and albumin.

The percentage of fat removed, based on the legal

standard, may be calculated by the following rule: Multiply the per cent. of fat in the milk by 100, divide the result by the legal standard for fat and subtract this from 100; or expressed as a formula:

The per cent. of fat removed $= 100 - \frac{F \times 100}{3.}$ This formula is true only for milks originally containing 3 per cent. of fat and so its results are generally much below the truth. For example, in a milk containing originally 5 per cent. of fat, which has been skimmed to 2.50 per cent., thus removing 50 per cent. of the fat in the milk, the above formula would indicate that only 16.6 per cent. of the fat had been removed. In most cases results nearer the actual truth are given by substituting 3.75 for 3 in the formula.

GENERAL METHOD FOR JUDGING WATERED AND SKIMMED MILK

Having found in a sample of milk (1) the per cent. of fat, (2) the specific gravity of the milk and (3) of the milk-solids, (4) the per cent. of solids, and (5) of solids-not-fat, one may arrive at fairly safe conclusions in regard to the watering and skimming by making comparison with the percentages of constituents present in average normal milk. In forming such conclusions, the following facts should be kept in mind:

1. Water has a lower specific gravity than milk.
2. Watering milk decreases (a) the lactometer reading, (b) the fat, (c) total solids, and (d) solids-not-fat.
3. Water has a higher specific gravity than milk-fat.

4. Skimming milk (a) increases the lactometer reading, (b) decreases the fat and total solids, (c) slightly increases the solids-not-fat, and (d) increases the specific gravity of the milk-solids.

5. Skimming and watering decrease all constituents, but lower the fat more in proportion than the solids and solids-not-fat.

6. Skimming and watering may produce the same specific gravity as in normal milk.

7. The amount of fat in milk is more variable than the amount of solids-not-fat.

8. Herd milk which shows a lactometer reading above 33.5, along with a low percentage of fat, and a specific gravity of solids above 1.40, can be regarded as skimmed.

9. Herd milk showing a lactometer reading below 28 may be regarded as watered, especially with low fat, solids and solids-not-fat.

Milk is watered when (1) the specific gravity of the milk is low, (2) the percentage of fat and solids-not-fat is low and (3) the specific gravity of the milk-solids is between 1.25 and 1.35.

Milk is skimmed when (1) the specific gravity of the milk and of the milk-solids is high; when (2) the per cent. of solids-not-fat is high, and when (3) the per cent. of fat and solids is low.

Milk is watered and skimmed when (1) the specific gravity of the milk is normal or otherwise, (2) the specific gravity of the milk-solids is normal or high, and (3) the per cent. of fat and solids-not-fat is low.

DETECTION OF FOREIGN SUBSTANCES IN MILK

The foreign substances most frequently found in milk are preservatives and coloring matters. The preservatives in common use are formalin, boric acid, borax and sodium bicarbonate. The coloring matters generally used are annatto and coal-tar dyes (azo-colors), which are added to milk to make it look rich, and, especially in case of skimmed and watered milk, to cover up the signs of such adulterations.

Test for annatto.—To 10 cc. of milk in a test-tube add 10 cc. of ether, shake vigorously and let stand until the ether separates on top of the milk. If annatto is present, the layer of ether will be yellow, the depth of color depending on the amount of annatto present.

Test for Coal-Tar Dyes.—The azo-colors, which are the ones most commonly used in coloring milk, may be detected by adding 10 cc. of milk to 10 cc. of strong hydrochloric acid and mixing, when a pink coloration appears.

Tests for Formalin.—Formalin, which is a 40 per cent. solution of formaldehyde, is commonly diluted and sold under such names as "Freezine," "Iceline," etc., which contain from 2 to 6 per cent. of formaldehyde. In making the Babcock test in milk, the presence of formalin may be shown when a marked violet layer forms at the junction of the acid and milk just after pouring the acid into the test-bottle. The test may also be performed by taking 10 cc. of milk in a test-tube or Babcock test-bottle, adding dilute ferric chloride and 5 cc. of sulphuric acid, such as is used in the Babcock test, pouring the acid down the side of the tube so that it does not mix with the milk.

Leach's test, which is more delicate, is performed as follows: Make a solution of hydrochloric acid (specific gravity 1.2) containing 2 cc. of 10 per cent. ferric chloride per liter. Add 10 cc. of this solution to 10 cc. of milk in a white teacup and heat slowly over a flame to boiling, giving the cup a rotary motion. If formalin is present, a violet coloration appears, varying in depth with the amount present.

Test for borax and boric acid.—To 25 cc. of milk add lime water, until the milk is alkaline, evaporate to dryness and burn to an ash in a small porcelain or platinum dish. To the ash add a few drops of dilute hydrochloric acid, not too much; then add a few drops of water and place in this water solution a strip of turmeric-paper (obtainable at drug-stores). Then dry the paper, when a cherry-red color will appear on the paper if either borax or boric acid is present. This test is made still more certain by moistening the reddened paper with a drop of an alkali solution, when the paper turns to a dark-olive color in the presence of borax or boric acid.

Test for sodium carbonate.—To 10 cc. of milk add 10 cc. of alcohol and a few drops of a 1 per cent. solution of rosolic acid. Carbonates are present if a rose-red color appears, while pure milk shows a brownish-yellow color.

ADULTERATIONS OF CREAM

The adulterants of cream are the same as those for milk and are detected in the same manner. Gelatine and sucrate of lime are used to some extent to give cream a greater consistency.

ADULTERATIONS OF BUTTER

The most common adulteration of butter is substitution, in part or in whole, of fat other than butter-fat, such as products from beef-fat and lard. Occasionally preservatives are found, such as occur in milk. "Renovated" or "process" butter is made from refuse butter that can not be disposed of otherwise on the market. Excessive water or casein should be regarded as an adulteration. Harmless coloring matter has been universally allowed. The absolute identification of such adulterants as oleomargarin requires somewhat elaborate chemical methods. Only simple tests can be given here.

Foam-test for oleomargarin and "renovated" butter.—Melt in an ordinary tablespoon a piece of the suspected butter about the size of a small chestnut, holding it over a small flame,—a candle flame will do. Stir the fat, while melting, with a match or similar stirrer. Then lower the spoon into the flame and let the fat boil vigorously, stirring thoroughly several times during the boiling and not neglecting the outer edges. Oleomargarin and "renovated" butter boil with marked noise, sputtering more or less and producing little or no foam. Genuine butter generally boils with much less noise and foams up vigorously.

Milk-Test for oleomargarin.—In a tin measuring-cup take about one gill of sweet milk or water, heat to about 140° F. and then add a slightly rounded teaspoonful of the suspected sample. Stir with a small piece of wood, about the size of a match or smaller, until the fat is melted. Then immerse the cup to about one-third of its height in a pan of water in which there

are several large pieces of ice. Stir the liquid continuously, alternating a circular and crosswise motion, until the fat hardens, when it can be easily collected into one lump by means of the wooden stirrer, if it is oleomargarin; but, if butter, the fat will form little granules and can not be collected in one lump. When milk is used in the test, it should contain as little fat as possible. In this test "renovated" butter behaves like genuine butter.

ADULTERATIONS OF CHEESE

Only two kinds of adulteration are common in American cheddar cheese: (1) The removal of fat in varying degrees producing so-called skim-cheese, and (2) the use of fat other than milk-fat, producing the so-called filled cheese. Harmless coloring matter is allowed. Cheese containing less than 32 per cent. of fat can be regarded as having been made from milk containing less than its normal amount of fat. The per cent. of fat in filled cheese is generally lower than in cheese made from normal milk.

CHAPTER XVI

The Babcock Test Applied to Farm Conditions

The Babcock test finds application on the farm of every dairyman in one or more of the following ways:

1) In testing the quality of milk in respect to fat produced by individual cows and by the herd.

(2) In testing cream.

(3) In testing skim-milk.

(4) In testing buttermilk.

(5) In testing milk and cream as a means of self-protection.

TESTING COWS

The most effective test of the value of a dairy cow is the production of milk and of milk-fat. Evidence has been carefully collected showing that many cows in this country are kept at an actual loss. The owners of such cows may be conscious of the fact that they are not prospering, but without having any idea of the cause. The amount of fat in milk required for various purposes differs somewhat. For ordinary market purposes, where consumers take as a matter of course any kind of milk delivered to them, the most profitable cow is the one producing a large yield of milk, which generally means a low percentage of fat, frequently just enough to keep above the legal standard. The statement applies to milk sold by bulk

or by weight alone, whether sold for direct consumption or taken to a cheese-factory or creamery. But whenever milk is paid for according to its percentage of fat, as in certain forms of market milk, at creameries, at condenseries, and at progressive cheese-factories, the cow producing the largest amount of milk-fat will nearly always be found the most profitable. As a rule, a pound of milk-fat can be produced at less cost in rich milk than in poor milk. The only method of ascertaining accurately the value of a cow or of a herd for the production of milk-fat is by testing the milk. The real object of a test is to find the total number of pounds of fat produced in the milk for a definite period of time, the most satisfactory unit being one period of lactation, that is, from the time of calving to the time of becoming dry.

In testing the value of a cow for the production of milk-fat, two factors must be considered: (1) The amount of milk produced and (2) the per cent. of fat in the milk. The first amount is obtained by weighing the milk, and the second by testing the milk by the Babcock test. From these data the amount of milk-fat produced is easily found.

In applying the Babcock test on the farm to individual cows, certain details need to be considered, such as (1) the duration of the testing, (2) the frequency of testing, (3) the method of sampling, (4) weighing the milk, (5) keeping records, and (6) calculating results. In carrying out the work of the milk-test, all necessary details are given in Chapter IV, p. 57.

Duration of testing.—For best results, the tests

should be made at intervals for a whole period of lactation.

Frequency of testing.—It is not practicable to test the milk of every milking for fat and it is not necessary. On the other hand, the testing of a single milking or of a day's milk or even of a week's milk is insufficient, since, for many reasons, the percentage of fat may vary greatly from one time to another. The following plan combines a high degree of accuracy with the least amount of labor: Make the first fat-test in about two weeks after the cow calves and then repeat it regularly once in two weeks during the period of lactation. Even a monthly testing will, however, give fairly accurate results.

Method of sampling.—When a single cow's milk is to be tested, the following precautions should be observed in taking the sample:

(1) The cow must be milked dry at the milking previous to the one to be tested. (2) On the day of milking for the test, the cow is milked as completely as possible each time. (3) After the morning's milking, the milk is well mixed by pouring from one pail to another or by stirring with a dipper, and about a gill is at once dipped out and poured into a pint fruit-jar, which has been thoroughly cleaned and scalded. The sample is kept in a cool place. Repeat the sampling with the evening's milk or with each milking, if the cow is milked more than twice a day, adding a sample of each to the jar containing the morning's milk. (4) Make a test before the milk can sour, mixing well before taking samples for the test by pouring back and forth a few times from one vessel to another. If

it is impossible to make the test promptly, add bichromate of potash to preserve the sample, as directed on p. 30. (5) In testing the milk of several cows at the same time, label each sample-jar with the number or name of the cow furnishing the milk. (6) If the milk is to be tested also for solids by the lactometer, take about a half-pint sample from each milking.

More strictly accurate results are secured if each milking is sampled by a tube, as stated on p. 27.

Weighing milk.—In testing a cow, the milk must always be weighed on the testing day immediately after the milking is completed. As it is so easy to weigh milk, it is desirable to weigh the milk at every milking, or, at least, on two or three days each week. Accurate spring scales of moderate cost are available.

Keeping records.—Records of each cow tested should be carefully kept, the following facts being recorded: (1) Date, (2) name of cow, (3) pounds of milk given, (4) per cent. of fat in milk, (5) lactometer reading, if desired.

Calculating results.—The following data can be derived by calculation from the facts recorded above: (1) Pounds of fat produced on day of test, (2) pounds of fat and milk produced each month, (3) pounds of fat and milk produced for one period of lactation.

The amount of fat on the day of the test is found by multiplying the total number of pounds of milk given by the per cent. of fat found and dividing by 100. For example, if the day's yield of milk is 25 pounds and the per cent. of fat is 4, the day's milk contains 1 pound of milk-fat. (See p. 253).

The amount of milk and fat produced each month

is found as follows, when the test is made once in two weeks: Add the daily yields of milk for the day of the test and for one week before and one week after the test, thus obtaining the milk yield for 15 days. Multiply this sum by the per cent. of fat found on the day of the test and the result is the fat yield for half a month. This added to the next half month gives the yield of fat for the month.

The monthly yields of milk and fat, added together at the end of the period of lactation, give the total yields for the period.

APPLICATION OF RESULTS OF TESTING INDIVIDUAL COWS

A progressive dairyman will discard from his herd any animal that can not produce, at least, 200 pounds of milk-fat in a year, especially if the milk is sold on the basis of its fat content; and he will aim, by means of intelligent breeding, feeding and care, to increase the annual yield of milk-fat to 250 or 300 pounds for each cow.

TESTING CREAM ON THE FARM

There are several conditions under which it is of advantage to test cream on the farm in order to know its fat content.

When a dairyman is producing cream to sell directly to consumers, it is important to know its percentage of fat, in order that it may be uniform from day to day, whatever the desired percentage may be. The work of the cream-separator may be controlled ad-

vantageously only by knowing the percentage of fat in the cream produced. In states where a certain percentage of fat in cream is required by law, it is important for the dairyman to know that his product is up to standard before he sells it.

In making butter on the farm, better results can be secured by having the cream of a uniform richness in fat, and the percentage of fat in cream can be accurately known and regulated only by testing.

TESTING SKIM-MILK AND BUTTERMILK ON THE FARM

The completeness with which fat is removed from milk by different methods of creaming, whether by separator or by gravity processes, can be known accurately only by testing the skim-milk for its fat content. With the knowledge furnished by testing, one is in position to prevent further losses when they are known to exist. Similarly, the efficiency of churning may be found by testing the buttermilk for its fat content.

TESTING MILK AND CREAM FOR SELF-PROTECTION

When dairymen sell milk or cream to milk-dealers, creameries, cheese-factories, shipping-stations, condenseries, etc., on the basis of the per cent. of fat in milk, it is often a matter of satisfaction to know that the tests which serve as a basis of payment are correct. If a dairyman will take pains to acquire the skill necessary to perform the operations of the Babcock test, he can satisfy himself easily in regard to the ac-

curacy of the tests of his milk made by others. In cases where a purchaser reports the test lower than it is, his dishonesty can be detected by means of home testing.

It is also important for the dairyman who sells milk directly to consumers to know that his milk is above the legal standard. Much annoyance and expense may sometimes be saved by knowing the percentage of fat and solids in the milk one sells.

CHAPTER XVII

Methods of Commercial Testing and Scoring of Butter and Cheese

In commercial transactions in butter and cheese, certain points or qualities have been adopted as a basis or standard in judging the commercial value of these products. The terms used in expressing the different qualities vary considerably in different market centers, and the same expression is used with different meanings by different persons. Frequently individuals use terms that are strictly local or personal. It is desirable that there should be a uniform usage and a common understanding in respect to the terms used in judging dairy products. The attempt is made here to discuss the terms in common use and to define them as well as may be, in the hope that it may serve as a beginning in bringing about a general agreement in respect to the use and understanding of the expressions employed in testing and scoring dairy products. The definitions here given can hardly be expected to be in full agreement with the usage of everyone, since individuals differ from one another so much in their use of these terms.

SAMPLING AND TESTING BUTTER

In obtaining a sample of butter from a package for examination, a butter-trier (Fig. 52) is used. This is inserted its whole length, if possible, into the but-

ter, turned around once and then drawn out, bringing with it a long, round plug as a sample. The plug, as soon as drawn, is examined for flavor by smelling and next by tasting. It is then broken across to examine the grain or texture, and then other qualities are examined in turn.

FIG. 52
BUTTER TRIER

TERMS USED IN DESCRIBING QUALITIES OF BUTTER

The qualities that have been selected to serve as a basis or standard in the commercial testing and scoring of butter are as follows: (1) Flavor, (2) texture, (3) body, (4) moisture, (5) color, (6) salt and (7) appearance.

Flavor.—By flavor is meant the quality that is perceptible to the senses of smell and taste. The sense of smell is, as a rule, capable of being developed so as to be more highly sensitive than the sense of taste in detecting variations of flavor. The flavor in normal butter is due to the formation of certain organic compounds in minute quantities during the cream-ripening process. What specific compounds these are has not yet been learned. The odor is not that of lactic acid, since that is odorless.

Testing Flavor.—The flavor is obtained by placing the plug of butter under the nose as soon as possible after the plug is drawn. A portion of the butter is also tasted.

Terms describing flavors.—The following terms are selected from the great variety of names that are applied to various flavors found in butter: (1) Perfect, (2) quick, (3) clean, (4) light, (5) buttermilk, (6) rancid, (7) tallowy, (8) cowy, (9) fishy, (10) tainted, (11) stable, (12) weedy, (13) cheesy.

(1) *Perfect* flavor applies to butter which possesses the characteristic aroma and taste of high-grade butter in a well-marked degree. It is difficult to describe this flavor adequately, but it is commonly characterized as nutty, clean, pleasantly aromatic, delicate and sweet. Perhaps the best description of it is to liken it to the flavor of clean, well-ripened cream. It should be entirely free from rancidity or any unusual flavor.

(2) *Quick* flavor is so delicate and volatile that it disappears quickly; "high" is also applied to the same condition.

(3) *Clean* flavor is free from every trace of unpleasant aroma or taste.

(4) *Light* or *flat* flavor in butter indicates absence of marked flavor, due to lack of cream-ripening, to excessive washing of granules and to other conditions.

(5) *Buttermilk* flavor is somewhat sour in taste and like buttermilk in aroma. It is due to the presence of an excessive amount of buttermilk in the butter.

(6) *Rancid* flavor is that of butyric acid, the presence of which is due to the use of over-aged cream or milk or to age of butter, in which butyric acid fermentation has occurred. When the flavor is strong, it produces an unpleasant, strangling or choking sensation in a sensitive throat. The odor is very penetrating and lasting.

(7) *Tallowy* flavor is like that of tallow.

(8) *Cowy* flavor refers to the animal odor, particularly as noticed in the breath of a cow. It appears to be especially prominent in cows freshly turned into pasture.

(9) *Fishy* odor is rather suggestive of salted codfish. It is usually due to a special form of fermentation appearing in the milk and cream.

(10) *Tainted* flavor covers a variety of odors and tastes that are offensive in varying degrees.

(11) *Stable* flavor is the one characteristic of cow manure.

(12) *Weedy* flavor includes such abnormal flavors as may come from onions, leeks, cabbages, turnips, etc.

(13) *Cheesy* flavor suggests the flavor of cheese and is due to fermentation changes in the proteid of butter; it is more common in unsalted butter.

Texture.—The texture of butter refers to what is called the grain and depends upon the condition of the butter-granules. In its first formation in churning, butter appears in very small, irregular grains or granules. These grains retain their individuality in large measure throughout the rest of the process of butter-making and even in the finished product. The more distinct the individuality of the granules can be kept in making the butter into a solid mass, the better is the texture.

Testing texture.—The granular texture of butter is seen when a plug or chunk of butter is broken into parts transversely, giving somewhat the fractured appearance seen in broken steel and free from a smooth, greasy appearance. Another method of testing tex-

ture is to pass a knife-blade or butter-trier through the butter; when it is withdrawn, the trier is clean and free from any greasy appearance, if the texture is good.

Terms describing texture.—The terms used to describe texture are (1) perfect, (2) poor grain, and (3) salvy.

(1) *Perfect* texture in butter is shown by the granular formation, as described above.

(2) *Poor* grain texture in butter is shown by less marked grain and a more or less smooth, greasy appearance on the broken surfaces.

(3) *Salvy* texture applies to butter in which the grain is more or less destroyed and the smooth, greasy appearance of the broken surface is very marked.

Defective texture in butter is caused by allowing the butter-granules in the churn to become too large and by working too much or at too high a temperature. The granular texture of butter is completely destroyed by warming butter to near its melting point.

Body.—By this term is meant the quality of consistency, firmness or hardness, as shown by not melting or softening too easily.

Testing body.—The body of a sample of butter can be ascertained by pressing a portion of the plug between the thumb and fingers, and also by pressing between the tongue and roof of the mouth.

Terms describing body.—The terms used to describe the body of butter are: (1) perfect, firm or solid, (2) hard or tallowy, (3) weak-bodied, (4) sticky.

(1) *Perfect* body in butter is shown by firmness or solidity under proper conditions of temperature. When pressed between the fingers or on the tongue it shows a certain amount of resistance.

(2) *Hard* or *tallowy* body is shown by excessive solidity, being characteristic of butter made from cows far along in lactation, or in the case of cows heavily fed on cotton-seed meal.

(3) *Weak-bodied* butter is lacking in firmness, more or less soft, melting more easily on warming than a perfect-bodied butter. Weak-bodied butters are usually salvy in texture and high in moisture. Certain feeds, such as gluten meal, tend to increase the softness of butter.

(4) *Sticky* body in butter is shown by extreme softness amounting to stickiness.

Moisture.—The water in butter should be so thoroughly incorporated with the fat that it does not appear in the form of free beads of water visible to the eye. Water should not run off the trier when a sample is drawn. The water should also be clear and transparent.

Testing moisture.—The sample of butter is examined for the appearance of moisture or brine in respect to the completeness of its incorporation and its clearness.

Terms describing moisture.—The following terms are used to describe the condition of moisture in butter: (1) Perfect, (2) excessive, (3) milky or turbid.

(1) *Perfect* moisture in butter is shown by the absence of any visible moisture in the form of drops.

(2) *Excessive* moisture is shown by the presence of

water easily apparent to the eye. Butter may sometimes contain so much water as to be called "mushy."

(3) *Milky* or *turbid* moisture or brine appears more or less milky, being due to the presence of too much buttermilk.

Relation of texture, body and moisture.—Considerable confusion prevails in the use of the terms texture, body and moisture. Some use the term texture to include also body and moisture; others use the term body to include texture, while others use the expression "body and grain" to cover all three qualities. Texture and body and moisture may be influenced by the same conditions and may be, to some extent, interdependent, but in reality they are distinct properties and, if they were treated as such, needless confusion would be avoided.

Color.—The color of butter varies in different markets according to requirements, but most of the butter made in the United States has, as its standard, an even, bright, straw-yellow. Most butter in commerce is colored artificially, so as to maintain a uniform appearance at all seasons of the year. Somewhat different shades of color are demanded by different markets.

Testing color.—The quality of color is tested simply by inspection with the eye. The thumb-nail is run along the surface of the plug near the edge of the trier, and the fresh surface thus made is examined. The examiner carries in his mind the shade of what he regards as an ideal color and judges the sample under examination by its comparison with his ideal. It would lead to easier methods of comparison and

more uniform results if there could be agreed upon a certain shade of color which should serve as a national standard as far as possible. Such a color standard could be furnished butter-makers and examiners of butter. Along with such a standard color, there could be prepared a scale of shades which could serve as a basis for scoring color.

Terms describing color.—The terms used in describing the color of butter are: (1) perfect, (2) light, (3) high, (4) reddish, (5) mottled, and (6) white-specked.

(1) *Perfect* color in butter is a straw-yellow, bright, and uniform throughout the mass. A plug of butter held between the light and the eye should be evenly translucent and not opaque or cloudy.

(2) *Light* color is shown by insufficient color, the yellow being too pale.

(3) *High* color is deeper yellow than called for by perfect color.

(4) *Reddish* color is self-explanatory and is due to excessive use of coloring material.

(5) *Mottled* color in butter is shown by the appearance of light-colored portions, which may be in spots or streaks or waves. The term *wavy* is often used to indicate a variation of color that is just perceptible. They are not seen as readily on a sample plug drawn by a trier as they can be by cutting a lump of butter across so as to show a smooth, broad surface. Slight mottling is apt to escape observation when the examination is made only of a plug. Mottling is due to the action of salt upon buttermilk retained in the butter. The light portions owe their color to the pres-

ence of the casein lactate of buttermilk. Removal of buttermilk from the butter-granules prevents mottling. (Bulletin No. 263, N. Y. Agr. Exp. Sta. 1905).

(6) *White-specked* color in butter appears in white specks of varying size, but usually small. They are due to particles of coagulated casein lactate produced in cream by over-ripening, and also to dried cream particles, caused by lack of stirring during the process of ripening.

Salt.—The amount of salt in butter varies with different markets; but, whatever the amount used, it should be completely dissolved and evenly distributed through the mass of butter.

Testing butter for salt.—The quality of butter as affected by salt is examined by tasting, sight and feeling. Undissolved particles of salt, when they can not be felt on the tongue or seen, can be detected by rubbing some of the butter between the fingers.

Terms describing salt.—The terms used in describing the quality of butter in relation to salt are the following: (1) Perfect, (2) too salty, (3) flat, (4) gritty, (5) uneven.

(1) *Perfect* quality in respect to salt in butter is shown as follows: The salt must be in the proportion demanded by the market; it must be entirely dissolved and evenly distributed.

(2) *Too salty* butter contains more salt than the market demands.

(3) *Flat* butter is lacking in salt for the market requirements.

(4) *Gritty* butter contains undissolved salt.

(5) *Uneven* salt in butter is lack of uniformity, some portions of butter being more salty than others.

Appearance.—Under this head are included the manner of packing, the attractive appearance of the package, cleanliness, etc.

Testing appearance.—When the cover of the package is removed for sampling the butter, the appearance of the surface of the butter is noticed. The outside of the package is also examined. The two general qualities that must be kept in mind in this connection are cleanliness and neatness.

Terms describing appearance.—The quality of appearance of butter may be considered under two heads, (1) finish and (2) package.

(1) *Finish* in appearance, in connection with examining butter, refers to the manner of packing. The finish is perfect when the package is lined with paraffin or with a good quality of parchment paper, neatly placed, and the package well filled, the surface being even and bright. The package should be just evenly full. The top should be neatly covered with cheesecloth saturated with brine.

(2) *Package.*—The package is regarded as perfect when of good material, well-made, clean, and neat in appearance. In the same lot of butter the packages should all be alike in size and shape.

SCORING BUTTER

The different qualities indicated above are used in a specific manner for judging and fixing the commercial value of butter.

Scale of points.—To each quality is assigned a definite numerical value and these numbers are called a *scale of points*. The following scale of points is in common use in many markets of this country, the numbers indicating perfect quality in each case, and the totals aggregating 100:

Flavor, 45 points.	Color, 15 points.
Texture, (10)	Salt, 10 points.
Body, (10) } 25 points.	Appearance, 5 points.
Moisture, (5)	Total, 100 points.

Method of scoring.—In scoring a sample of butter, an examination is made with reference to each of the qualities mentioned. In those qualities in which it is perfect, it is given the values or points assigned above. If the butter is defective in any quality, that is, short of perfect, then a smaller value is given than the one indicated above in the scale of points; the more defective the butter is in any quality, the lower is the value or number of points given it. When all the qualities have been scored, the numbers of points assigned to them are added and the total is the score of the butter under examination.

It can readily be seen that judgment, trained by experience, is required to assign to each quality its proper number of points. The sense of smell and of taste must be highly developed by training in the field of experience. The eye and touch must also be trained by special experience.

Score-cards.—For convenience, score-cards are used in keeping records of the results of scoring where many samples are examined. The following form illustrates a commercial score-card:

NAME OR NUMBER IDENTIFYING SAMPLE.....

DATE..... JUDGE.....

QUALITY	SCORE-POINTS	*Sample* 1	*Sample* 2	*Sample* 3	*Sample* 4
Flavor.....	45	45	40	36	32
Texture.....	10	8	10	8	7
Body.....	10	10	8	8	7
Moisture.....	5	5	3	4	4
Color.....	15	13	14	13	12
Salt.....	10	10	10	10	8
Appearance.....	5	4	5	4	5
		95	90	83	75

These scores, under the system of grading described below, would be graded as follows: Sample 1, "extras;" sample 2, "firsts;" sample 3, "seconds;" and sample 4, "thirds."

In commerical scoring, reasons for the number of points given are not stated; but in dairy schools and competitive public exhibitions, where educational purposes are in view, the reason for each score should be given. The following form of score-card for such purposes is a suggestion, which may be modified to suit any special conditions:

Butter-Scoring—Numerical and Descriptive Card

Date ..... Judge .....

Name or number identifying butter .....

NUMERICAL SCORE.

Perfection—	Flavor, (45)	Texture, (10)	Body, (10)	Moisture, (5)	Color, (15)	Salt, (10)	Appearance (5)
Score given	—	—	—	—	—	—	—

DESCRIPTIVE SCORE (check defects below).

Flavor	*Texture*	*Body*	*Moisture*	*Color*	*Salt*	*Appearance*
Perfect	Quick	Perfect	Perfect	Perfect	Perfect	Finish
Clean	Light	Poor-grain	Firm	Excessive	Light	Too salty	Package
Buttermilk	Rancid	Salvy	Hard	Milky	High	Flat
Tallowy	Cowy		Weak-bodied		Reddish	Gritty
Fishy	Tainted		Sticky		Mottled	Uneven
Stable	Weedy	Cheesy			Wavy Specks		

CLASSES AND GRADES OF BUTTER

The following system for classifying and grading butter is taken from the regulations of the New York Mercantile Exchange:

Classification:—

1. *Creamery Butter* includes butter made in a creamery from cream obtained by the separator system, or from gathered cream.

2. *Imitation Creamery Butter* includes butter churned by the dairyman, collected in its unsalted, unworked condition, and worked, salted and packed by the dealer or shipper.

3. *Dairy Butter* includes such as is made, salted and packed by the dairyman and offered in its original package.

4. *Factory Butter* is butter collected in rolls, lumps,

or in whole packages, and reworked by the dealer or shipper.

5. *Renovated Butter* is that made by taking pure butter and melting the same and rechurning with fresh milk, cream or skim-milk, or other equivalent process.

6. *Grease* consists of all grades of butter below Fourths free from adulteration.

7. *Known Marks* is a term used to include such butter as is known to the trade under some particular mark or designation and must grade as Extras, if creamery, and as Firsts, if reworked butter, in the season in which it is offered, unless otherwise specified.

Grades:—Grades of butter must conform to all the following requirements and are not determined by score alone.

1. *Extras* must be of the highest grades of butter made in the season when offered under the different classifications; 90 per cent. shall be up to the following standard and the balance must not grade below Firsts: (1) Flavor must be fine, sweet, clean and fresh, if of current make; and fine, sweet and clean, if held. (2) Body must be firm, smooth and uniform. (3) Color should be a light straw shade, even and uniform. (4) Salt should be medium. (5) Package should be good, uniform and clean. (6) Score must average 93 points or higher.

2. *Firsts* is a grade just below Extras and must be fine butter for the season when made and offered, under the different classifications, and up to the following standard:

(1) Flavor must be good, sweet, clean and fresh, if of current make; and good, sweet and clean, if held. (2) Body must be good and uniform. (3) Color must be reasonably uniform, neither too high nor too light. (4) Salt should be medium. (5) Packages should be good and uniform. (6) Score must average 87 points or higher.

3. *Seconds* is a grade just below Firsts and must be good for the season when offered under the different classifications, and up to the following standard:

(1) Flavor must be reasonably good and sweet. (2) Body, if creamery or dairy, must be solid-boring. If factory or renovated, must be 90 per cent. solid-boring. (3) Color must be fairly uniform. (4) Salt may be high, medium or light. (5) Package should be good and uniform. (6) Score must average 80 points or higher.

4. *Thirds* is a grade just below Seconds.

(1) Flavor must be reasonably good; may be strong on top and sides. (2) Body should be fair-boring, if creamery or dairy, and at least 50 per cent. boring a full trier, if factory or renovated. (3) Color may be irregular. (4) Salt may be high, light or irregular. (5) Packages should be fairly uniform. (6) Score must average 75 points or higher.

5. *Fourths* is a grade just below Thirds and may consist of promiscuous lots.

(1) Flavor may be off and strong on tops and sides. (2) Body is not required to draw a full trier. (3) Color may be irregular. (4) Salt may be high, light, or irregular. (5) Package may be of any kind mentioned at time of sale.

SAMPLING AND TESTING CHEESE

Only the ordinary American cheese, usually made by the cheddar system, is here considered. For commercial testing, cheese is sampled by a cheese-trier in much the same manner as butter. The plug should always be drawn from the top and not from the side in order to avoid injuring the protective power of the bandage. The plug drawn is examined by smelling, feeling, appearance, etc., in reference to the various qualities mentioned below.

TERMS USED IN DESCRIBING QUALITIES OF CHEESE

The following qualities have been selected to serve as a basis in the commercial testing and scoring of cheese: (1) Flavor, (2) texture, (3) body, (4) color, (5) salt, and (6) appearance.

Flavor.—By flavor is meant the quality that is perceptible to the smell and taste. The sense of smell is depended upon in testing flavor in cheese much more largely than is the sense of taste, because, in examining a large number of samples of cheese in succession, constant tasting soon dulls not only the sense of taste but also that of smell. Flavor in cheese is due to the formation of some unknown compound or compounds during the ripening process.

Testing flavor in cheese.—The flavor is best obtained by direct smelling of the plug as soon as it is drawn and, in addition, by crushing and warming some of the cheese in the hand and then smelling.

Terms used in describing cheese flavors.—From a great variety of names applied to various flavors

found in cheese, the following terms are selected for consideration: (1) Perfect, (2) high or quick, (3) clean, (4) low or flat, (5) strong, (6) too much acid, (7) too little acid, (8) sour, (9) sweet or fruity, (10) rancid, (11) tallowy, (12) tainted, (13) stable, (14) weedy, (15) bitter, (16) cowy.

(1) *Perfect* flavor applies to cheese when it somewhat resembles that of first-class butter with an added quality of its own that is characteristic but cannot be described further than to call it cheese-like. It is sometimes described as "nutty." This flavor should be marked, but not strong. It should be free from all other flavors, particularly the more or less offensive products of undesirable fermentations. The taste should be mild and somewhat lasting, but should not be so sharp as to "bite" the tongue.

(2) *High* or *quick* flavor is a delicate flavor that disappears quickly.

(3) *Clean* flavor is free from every trace of unpleasant aroma or taste.

(4) *Low* or *flat* flavor applies to slight traces, or absence, of flavor; it is insipid.

(5) *Strong* flavor is a good flavor very pronounced but free from everything offensive; it is a good flavor strongly developed.

(6) *Too much acid* applies to flavor that smells somewhat sour but does not taste sour.

(7) *Too little acid* applies to a mild flavor, lacking in character.

(8) *Sour* flavor is characterized by a sour taste when the cheese is fresh, owing to the presence of too much whey.

(9) *Sweet* or *fruity* flavor is suggestive of artificial pineapple odor and is somewhat "sickish."

(10) *Rancid* flavor is that of butyric acid, more common in old cheese than in young. When very strong, it affects a delicate throat with a slight sensation of choking or strangling.

(11) *Tallowy* flavor is like that of tallow.

(12) *Tainted* flavor includes a variety of odors, mildly to strongly offensive.

(13) *Stable* flavor suggests the smell of cow-manure.

(14) *Weedy* flavor applies to such abnormal flavors as come from onions, leeks, cabbages, ragweed, etc.

(15) *Bitter* flavor is self-descriptive. It is often due to certain fermentations that develop when a cheese is undersalted.

(16) *Cowy* flavor is suggestive of the breath of a cow and may develop in cheese from some form of fermentation.

Texture.—Texture, as applied to cheese, refers chiefly to compactness or appearance of solidity, and has a meaning quite different from what it has when used with reference to butter. It is quite common to regard the "body" as a part of the texture, but the two qualities are clearly distinct.

Testing texture in cheese.—The texture of cheese is tested by an examination of the plug with reference to the presence of holes. The plug is broken in two and the broken ends examined for the characteristic flinty appearance.

Terms describing texture.—The following terms are among those most commonly used in describing

texture: (1) Perfect, (2) close, (3) loose, (4) mechanical holes, (5) gas or pin-holes, (6) Swiss holes.

(1) *Perfect* texture in cheese is shown when a plug or a cut surface of the inside of the cheese presents to the eye a solid, compact, continuous appearance, free from breaks, holes and chunks. When a plug is broken in two, it should show a flaky appearance, termed a "flinty" break, resembling the surface of broken flint or steel.

(2) *Close* texture describes the appearance of a cut surface of cheese when free from all kinds of holes.

(3) *Loose* or *porous* texture is indicated by lack of solid compactness, being more or less full of holes, which vary from a few to enough to make a spongy appearance.

(4) *Mechanical holes* in cheese are irregular, open spaces, caused by the incomplete cementing of the pieces of curd in the press.

(5) *Gas-holes* or *pin-holes* are small holes, produced by gaseous products of fermentation.

(6) *Swiss holes* are fairly large, round holes, such as are present in Emmenthaler cheese.

Body.—This term, used in connection with cheese, refers to the consistency, firmness or substance of cheese. It is largely influenced by the amount of fat and moisture in cheese.

Testing body.—This quality is found by pressing a piece of cheese between the thumb and fingers.

Terms describing body.—The following terms are among those used in describing the body of cheese: (1) Perfect, (2) solid or firm, (3) smooth, (4) silky, (5) waxy, (6) pasty or salvy, (7) stiff, corky, or

curdy, (8) weak-bodied, (9) mealy, (10) gritty, (11) watery, (12) over-dry.

(1) *Perfect* body in cheese is indicated when it feels solid, firm and smooth in its consistency or substance. It does not crumble under pressure. A plug drawn from a cheese of perfect body should be smooth in appearance and not "fuzzy."

(2) *Solid* or *firm body* is indicated when cheese offers a certain amount of resistance under pressure, somewhat like that shown by a piece of fat pork or cold butter. The term *meaty* is also used.

(3) *Smooth*-bodied cheese, when pressed between the thumb and fingers, feels smooth and velvet-like, as distinct from harsh, gritty or mealy.

(4) *Silky*-bodied cheese is smooth in feeling but not over-solid in consistency.

(5) *Waxy*-bodied cheese is much the same as silky but possessing more firmness or solidity.

(6) *Pasty* or *salvy* cheese is very soft, usually from an excess of moisture. When pressed, it sticks to the fingers.

(7) *Stiff, corky* or *curdy* cheese is hard, tough, overfirm; it does not crush down readily when pressed in the hand.

(8) *Weak*-bodied cheese is very soft, lacking in firmness but not necessarily sticky like pasty cheese.

(9) *Mealy* cheese breaks down in fine crumbs when pressed.

(10) *Gritty*-bodied cheese feels harsh and gritty under pressure.

(11) *Watery*-bodied cheese is excessively soft, pasty and sticky.

(12) In an *over-dry* cheese the body is very hard or mealy.

Color.—The color of cheese varies considerably, whether artificially colored or not. There appears to be an increasing demand for uncolored cheese. The coloring varies from a pale yellow to a reddish yellow, according to the demands of special markets.

Testing color.—The color is tested by inspection with the eye, the examiner noticing particularly unevenness and any extreme condition of color.

Terms describing color.—Color in cheese is described by the following terms: (1) Perfect, (2) straight, (3) translucent, (4) white specks, (5) streaked, (6) wavy, (7) mottled, (8) acid-cut, (9) high, (10) light, (11) uncolored.

(1) *Perfect* color in cheese is indicated by evenness of color throughout the mass. A plug held between the eye and light should appear somewhat translucent.

(2) *Straight* color is an even, uniform color through the whole cheese.

(3) *Translucent* applies to color in cheese which appears slightly translucent when the plug is held between the eye and the light.

(4) *White specks* is a term that describes itself. Such specks in cheese are a defect. They may appear in cheese cured at low temperature.

(5) *Streaked* color indicates that there are light-colored portions in the form of streaks.

(6) *Wavy* color applies to lighter portions appearing in the form of waves.

(7) *Mottled* color shows in cheese in lighter-colored spots of fairly large size, more or less irregular.

(8) *Acid-cut* color is shown in cheese when considerable portions of the cheese have been made lighter in color by the presence of too much acid (whey).

(9) *High* color is indicated by a reddish color, caused by using too much coloring matter. However, the question of color is a relative one, because the demand in different markets varies from uncolored to extremely high color.

(10) *Light* color is the term usually used in describing cheese that has been made uniformly dead white by the action of too much acid (whey).

(11) *Uncolored* cheddar cheese is not white but of a light amber shade.

Salt.—The amount of salt in cheese varies somewhat with different markets. There is seldom experienced difficulty of uneven salting in cheese, because the salt slowly permeates the cheese in the ripening process. Little variations usually occur in different parts of the same cheese, but are so slight as to be incapable of being noticed by ordinary methods of examination.

Testing cheese for salt.—The quality of cheese as influenced by the salt is found simply by tasting.

Terms used in describing salt.—In describing the relation of salt to cheese, the following terms are used: (1) Perfect, (2) too much, (3) too little.

(1) *Perfect* applies to salt in cheese when just enough has been used to impart a sufficient taste of salt.

(2) *Too much* salt is indicated by salty taste. Too much salt in cheese causes a dry, mealy texture, overfirm body and imperfect flavor.

(3) *Too little* salt is shown by insipidity of taste.

It is usually accompanied by bitter flavor and porous texture.

Appearance.—This term refers to the general appearance of the cheese to the eye in respect to uniformity, neatness and cleanliness. It may also include the boxing. One system, as in the case of butter, describes under "finish" the appearance of the cheese, and under "packages" the boxing; and we will follow this method here.

Testing appearance.—When the cover of the box is removed for sampling, in the case of boxed cheese, the appearance of the cheese is noticed and the box itself is examined. Cleanliness and neatness are the points to observe in judging appearance.

Terms describing appearance.—The general terms used in describing appearance are (1) finish and (2) package.

(1) *Finish* in appearance, in order to be *perfect*, must meet the following requirements: The rind must be smooth, even in color, free from cracks and fairly hard. The bandage must be without wrinkles and must be neatly rounded over the edges about an inch and a half on each end of the cheese. The sides of the cheese should be straight and of uniform height all around.

The faults of appearance in finish are as follows, the terms being self-descriptive: (1) Cracks, (2) light spots, (3) roughness in rind, (4) uneven edges, (5) wrinkles in bandage, (6) lack of uniformity in ends and in height, (7) bulging out at sides or ends.

(2) *Package.*—The packages or boxes are regarded as perfect when of good material, well made, strong,

clean, close-fitting, uniform in size and in undamaged condition.

SCORING CHEESE

The qualities described in the preceding pages are used for judging and fixing the commercial value of cheese.

Scale of points.—The following scale of points is in use in many places, the numbers indicating perfect quality in each case and the totals aggregating 100:

Flavor, 50	Body, 15	Salt, 5
Texture, 15	Color, 10	Appearance, 5

In the practice of many markets, salt is omitted and appearance is given 10 points.

Method of scoring.—The general procedure is essentially the same as that already described in connection with butter (p. 160).

Method of grading cheese.—The same general principles apply as in grading butter (p. 231). One classification is into (1) "fancy," (2) "firsts," and (3) "seconds." In the Canadian market, there are first, second and third grades.

Score-cards for cheese can be prepared in a manner similar to those previously suggested for butter (p. 230).

As in the case of butter, the testing, scoring and grading of cheese demand good judgment trained by experience. The sense of smell and touch must be well developed.

No formal classification or grading of cheese is made by the New York Mercantile Exchange, as is done in the case of butter.

CHAPTER XVIII

Methods of Commercial Testing and Scoring of Milk and Cream

In the past few years, there has been a growing sentiment that some method of testing the commercial value of milk and cream, similar to that used in judging butter and cheese, is much needed. Some helpful work has been done in this direction by the Dairy Division of the U. S. Department of Agriculture. The writer believes an efficient system will be developed in the near future, and, as a basis for such a system, the present discussion is offered.

For convenience of treatment, we will classify milk and cream according to the purposes for which they are used, as follows: (1) Market milk and cream, when sold for direct consumption as such. (2) Creamery milk and cream, when used for butter-making. (3) Cheese-factory milk, when used for cheese-making. (4) Certified and standardized milk, when produced under specific sanitary conditions and reaching a guaranteed standard of composition.

TERMS USED IN DESCRIBING QUALITIES OF MARKET MILK

The qualities that are selected as a basis in the commercial testing and scoring of milk are the following: (1) Composition, (2) keeping-power, (3) flavor, and, we may add, though of minor importance, (4) color,

and (5) appearance. For all practical purposes color and package can be omitted. In educational competitions they may be included.

Composition.—By composition is meant the per cent. of fat and of solids-not-fat in milk. The composition of milk, other things being equal, is the direct and only practicable measure of value as food, and this must constitute an important factor in judging the value of market milk.

Testing composition.—The percentages of fat and of solids-not-fat are found in the manner described on p. 57 and p. 185.

Terms describing composition.—Only two terms need to be used in describing the composition of milk: (1) perfect and (2) defective.

(1) *Perfect,* as applied to testing and scoring milk, means milk containing not less than 4 per cent. of fat and not less than 9 per cent. of solids-not-fat.

(2) *Defective* applies to milk containing less fat or solids-not-fat than required for milk of "perfect" composition.

The figures selected to indicate milk "perfect" in composition represent as nearly as possible normal milk of average composition. Injustice would obviously be done by selecting 4.5 or 5 per cent. as the amount of fat to represent milk perfect in composition. It would, on the other hand, be very unsatisfactory to take a so-called legal standard as representing perfect composition, because it is not a standard at all but simply a method of prescribing the lowest permissible amounts of fat and solids that will be legally tolerated in milk.

Keeping-power is an expression used to indicate in a general way the length of time milk remains sweet and palatable for direct consumption. In estimating the commercial value of milk, this is an important factor; since milk that is sour or otherwise unpalatable, or milk containing the products of any form of undesirable fermentation, is comparatively valueless for direct consumption, however rich it may be in fat and other solids. Keeping-power is a matter of much importance in warm weather, especially in the case of milk that is transported long distances before reaching the consumer.

Testing keeping-power.—The keeping-power of milk is tested by making determinations of (1) the acidity (p. 131), (2) the dirt in suspension (p. 163), (3) the fermentation test (p. 155), and (4) the number of bacteria (when practicable).

Terms describing keeping-power.—The terms used in describing the keeping-power of milk are (1) perfect, (2) acidity, (3) dirt in suspension, (4) undesirable fermentations, and (5) number of bacteria per cubic centimeter.

(1) *Perfect.*—Milk is called perfect in keeping-power (a) when its acidity is not above 0.18 per cent., (b) when it contains no dirt in suspension, (c) when the fermentation test reveals nothing abnormal, and (d) when the number of bacteria does not exceed 100,000 per cubic centimeter.

(2) *Acidity* is used to mean the amount of apparent total acid calculated as lactic, as shown by the amount of alkali neutralized. For discussion of the relation of acidity to the temperature and cleanliness of milk, see pp. 154.

(3) *Dirt in suspension.* The amount of dirt suspended in milk may usually be regarded as a rough measure of the germ content or cleanliness of milk, since the visible dirt we find in milk is generally the same in source and kind.

(4) *Undesirable fermentations* refer to the results of the fermentation test. They may reveal themselves in causing porous, spongy curd and in producing offensive odors.

(5) *Number of bacteria per cubic centimeter* is a self-descriptive term.

Flavor, applied to milk, is used to mean the odor and taste. The abnormal odors and tastes noticeable in market milk, otherwise good, come from three sources: (1) From certain things eaten by the cow, as leeks, onions, rag-weed, cabbage, etc. (2) From the direct absorption of strong-smelling substances present in the air surrounding the milk, such as manure, tobacco smoke, ensilage, etc. (3) From stable filth dropping bodily into the milk.

Testing flavor.—This is done by tasting and smelling the milk. The presence of abnormal odors can be more readily perceived by heating the milk for a few minutes to 100° F. in a closed bottle or jar and then smelling at once on opening the vessel.

Terms describing flavor.—The following terms may be used in describing the flavor of market milk: (1) Perfect, (2) stable or cow manure, (3) cowy or animal, (4) weedy, caused by leeks, rag-weed, etc., (5) vegetable, such as cabbage, turnip, ensilage, etc., (6) bitter, (7) fishy, (8) sour, (9) tainted.

(1) *Perfect* flavor in market milk is indicated by

freedom from all traces of abnormal odor and taste. There should be no marked odor and no trace of any offensive smell. The taste should be palatable, slightly saline and rich, without any unpalatable after-taste. It should not be flat or insipid.

The other terms are mostly self-descriptive. Their number could be extended to cover more minute details. The term *tainted* is used to cover miscellaneous offensive flavors not included under other terms.

Color in relation to the testing and scoring of market milk explains itself. It is in itself of little practical importance and may usually be omitted except in case of educational competitions.

Testing color.—The milk is examined for color by direct inspection in a clear light.

Terms describing color.—In describing the color of market milk, the following terms may be used: (1) Perfect, (2) white, (3) bluish, (4) high color, (5) reddish.

(1) *Perfect* as applied to color in milk indicates a yellowish color, not too pronounced, strikingly different from the white or bluish color of skim-milk, but not as deep as the color of cream.

The other terms explain themselves. High color may be caused by artificial coloring, usually producing a reddish tint.

Appearance.—This term refers to the appearance of the can, bottle or other vessel containing the milk and applies to these in respect to uniformity, neatness and cleanliness. This is of relatively small practical importance and may usually be omitted in commercial work. It finds a use in educational competitions.

SCORING MARKET MILK

The qualities described above are intended for use in the commercial judging and scoring of market milk. For practical purposes it will be sufficient ordinarily to make use of the first three qualities mentioned, viz: (1) composition, (2) keeping-power, and (3) flavor.

Scale of points.—In fixing a scale of points, we have a score of 100 to distribute among the three qualities last mentioned. How many points of the 100 shall be assigned to each? Here is a chance for wide variation of opinion. In actual experience, flavor does not hold the same important relation to market milk that it does to cheese and butter. A flavor that is imperceptible in the ordinary consumption of milk usually becomes concentrated in the process of butter-making or cheese-making and seriously affects the quality of the final product. A flavor must be very bad to render milk useless for cooking or for purposes other than direct drinking. Hence, flavor should not receive so high a score in the case of market milk as in the case of butter or cheese. On the other hand, composition should receive a relatively high score, since, other things being equal, it alone governs the relative values of different milks. The importance of keeping-power has already been considered. For the various reasons given, the following scale of points is suggested as a desirable one for practical use:

Composition	40
Keeping-power	30
Flavor	30

The numbers indicate perfect quality in each case and the totals aggregate 100. The numbers assigned could be varied considerably and still give equally satisfactory results in practise.

Method of scoring.—The milk is examined in the manner previously described and defects are indicated by making deductions from the perfect score in the following manner:

(1) *Composition.*—The perfect score of 40 points is reduced one point for each 0.1 per cent. below 4 per cent. of fat and one point for each 0.1 per cent. below 9 per cent. of solids-not-fat.

(2) *Keeping-power.*—The perfect score of 30 is to be reduced (a) one point for each 0.01 per cent. of acidity above 0.18; (b) a certain number of points, according to the judgment of the examiner, for dirt in suspension; (c) a certain number of points for any abnormal results shown by the fermentation test; and (d) one point for each 100,000 bacteria above 100,000 in 1 cubic centimeter of milk, when this determination is made.

(3) *Flavor.*—The perfect score of 30 is reduced by the presence of abnormal odors or tastes, the examiner using his judgment as to the amount of reduction.

JUDGING MILK FOR MANUFACTURE OF BUTTER AND CHEESE

For milk that is to be used for butter-making or cheese-making, a somewhat different method is suggested for judging and scoring. Since such milk is or should be paid for on the basis of the fat, the sys-

tem of judging and scoring should be such as to affect the value or the amount of the fat for which payment is received. Such a method is given in the following statements:

(1) Score the milk directly for two qualities only, (a) keeping-power and (b) flavor. For perfection, allow 50 points for keeping-power and 50 points for flavor.

(2) From the total amount (pounds) of fat contained in the milk furnished by each patron, deduct, according to the results of scoring, a certain amount of fat, which is found by multiplying the total amount of fat in the milk by 0.25 per cent. and this result by the number of points scored below 100.

(3) Use the number of pounds of fat thus found as the actual amount of fat on which to base dividends. To illustrate, a patron furnishes 1,000 pounds of milk, containing 4 per cent. of fat, which scores 90 in keeping-power and flavor. What deduction shall be made from the fat for the score of 90? The amount (1,000 pounds) of milk furnished contains 40 pounds of fat. This number (40) multiplied by 0.25 per cent. (Rule 1, p. 253) equals 0.1 pound of fat, which multiplied by 10, the number of points scored below 100, equals 1 pound. The total amount (40 pounds) of fat, diminished by the subtraction of 1, leaves 39 pounds, which amount would be used as a basis in making this patron's dividend.

The judging of flavor and keeping-power is carried out as previously described for market milk. In cheese-making, it is important to make full use of the fermentation test (p. 155).

COMMERCIAL TESTING AND SCORING OF CERTIFIED AND STANDARDIZED MILK

Certified milk usually guarantees (1) the per cent. of fat, (2) the per cent. of total solids or solids-not-fat, and (3) bacteria below a specified number. *Standardized* milk usually guarantees only the per cent. of fat.

The examination and scoring of certified or of standardized milk are conducted in the same manner as in the case of market milk, except that the scoring is based upon the guarantees, so far as these are given. The guaranteed per cent. of fat and of solids-not-fat and the number of bacteria are to be taken as representing the perfect score in place of the figures given above for market milk, and deductions from the perfect score for defects are made on the basis of the guarantees. For example, if a certified milk is guaranteed to contain 5 per cent. of fat, then, in order to score 40 in composition, the milk must contain 5 per cent. of fat and, in case of any shortage, a proportionate deduction should be made from the perfect score of 40.

COMMERCIAL TESTING AND SCORING OF CREAM

Market cream is that which is sold for direct consumption. The method of examining and scoring market cream is essentially the same as in the case of market milk. In composition, cream is not examined or scored for solids but for fat only. Another quality might be added in case of cream, that of *body*.

by which is meant the consistency of the cream, especially with reference to the presence or absence of lumps, complete evenness of consistency being required for perfection of body.

In composition, not less than 20 per cent. of fat should be used as a basis for perfection and from the perfect score of 40 is deducted one point for each 0.5 per cent. of fat below 20. Acidity and flavor are of special importance in market cream. The acidity should not be allowed to be above 0.2 per cent. for perfect cream.

Creamery cream is that which is intended for butter-making. The same general procedure is employed as in the case of milk that is to be used for butter-making, which, adapted to cream, is as follows:

(1) Score the cream directly for two qualities only, (a) keeping-power and (b) flavor. For perfection allow 50 points for each quality.

(2) From the total amount (pounds) of fat contained in the cream furnished by each patron deduct, according to the results of scoring, a certain amount of fat, which is found by multiplying the total amount of fat in the cream by 0.25 per cent. and this result by the number of points scored below 100.

(3) Use the number of pounds of fat thus found as a basis for making dividends.

To illustrate, a patron furnishes 500 pounds of cream, containing 20 per cent. of fat, which scores 90 in keeping-power and flavor. What deduction shall be made from the fat for the score of 90? The amount (500 pounds) of cream furnished contains 100 pounds of fat. This number (100) multiplied by 0.25 per

cent. (Rule 1, p. 253) equals 0.25 pound of fat, which multiplied by 10, the number of points scored below 100, equals 2.5 pounds. The total amount (100 pounds) of fat, diminished by the subtraction of 2.5, leaves 97.5 pounds of fat, which amount would be used as a basis in making this patron's dividend.

CHAPTER XIX

Arithmetic of Milk and Milk Products

In connection with the testing of milk and milk products, especially in some of the practical applications, various arithmetical calculations are often necessary. Special attention may need to be given to the methods employed in solving such problems as are presented, and a few pages are here devoted to the treatment of some of the more common problems in a systematic, comprehensive form, convenient for ready reference. In creameries, cheese-factories, etc., where much arithmetical work is involved in making dividends, saving of time is effected by using calculations or tables, which are published in book form.

I. FINDING WEIGHT OF ANY CONSTITUENT

Rule.—To find the weight of any constituent in milk or milk products, when the weight of the milk or its product and the per cent. of the constituent are known, *multiply the weight by the number indicating the per cent. of the constituent and divide the result by* 100. Example: How many pounds of fat in 675 pounds of milk testing 4.6 per cent. of fat? $\frac{675 \times 4.6}{100} = 31.05$, the number of pounds of fat.

EXAMPLES FOR PRACTICE

(1) How many pounds of fat in 2,000 pounds of cheese containing 35 per cent. of fat?

(2) How much water in 1,000 pounds of butter containing 14.5 per cent. of water?

(3) How many grams of milk-sugar are there in 500 grams of milk containing 5 per cent. of milk-sugar?

(4) How much fat is there in 1,200 pounds of cream testing 44 per cent. of fat?

(5) How much fat is there in 5,000 pounds of skim-milk testing .15 per cent. of fat?

2. FINDING PER CENT. OF ANY CONSTITUENT

Rule.—To find the per cent. of any constituent in milk, etc., when the weight of the milk, etc., and the weight of the constituent are known, *multiply the weight of the constituent by* 100 *and divide the result by the weight of the milk, etc.* Example: What is the per cent. of fat in 675 pounds of milk containing 31.05 pounds of fat? $\frac{31.05 \times 100}{675} = 4.6$ per cent.

EXAMPLES FOR PRACTICE

(1) What is the per cent. of fat in 120 pounds of butter containing 96 pounds of fat?

(2) What is the per cent. of water in 600 pounds of cheese containing 210 pounds of water?

3. FINDING PER CENT. OF SOLIDS IN MILK

Rule.—To find the per cent. of solids in milk when the Quevenne lactometer reading and the per cent. of fat are known, *divide the lactometer reading by* 4, *and to the result add the per cent. of fat multiplied by* 1.2. (See p. 137.)

4. FINDING PER CENT. OF SOLIDS-NOT-FAT IN MILK

Rule.—To find the per cent. of solids-not-fat in milk when the Quevenne lactometer reading and the per cent. of fat are known, *divide the lactometer reading by* 4, *and to the result add the per cent. of fat multiplied by* .2. (See p. 137.)

EXAMPLES FOR PRACTICE UNDER RULES 3 AND 4

(1) What is the per cent. of solids in milk testing 4 per cent. of fat and showing a lactometer reading of 32?

(2) What is the per cent. of solids-not-fat in the same milk as in (1)?

(3) What is the per cent. (a) of solids and (b) of solids-not-fat in a milk testing 2.5 per cent. of fat and showing a lactometer reading of 27?

(4) What is the per cent. (a) of solids and (b) of solids-not-fat in milk testing .2 per cent. of fat and showing a lactometer reading of 36?

5. FINDING THE "OVERRUN" IN BUTTER-MAKING

The weight of butter produced is greater than the amount of fat in the milk or cream from which the butter is obtained, because butter, in addition to its fat, contains water, salt and curd. Such excess is called the "overrun" and may be readily ascertained by finding the yield of butter for one pound of fat. While some milk-fat is lost in the skim-milk and buttermilk and in handling during butter-making, enough water, salt and curd are added to the fat to make up these losses and something more. The amount of butter yield for a pound of fat in milk or cream necessarily varies with the variation of losses of fat in skim-milk and in butter-making and the amount of water, salt, etc., retained in the butter. Hence the "overrun" varies. When the operations of skimming milk and butter-making are properly managed, one pound of fat in milk produces about 1.17 (about 1 1-6) pounds of butter. Hence, the "overrun" is .17 or one-sixth, (17 per cent). The "overrun" in case of cream averages about .03 higher than in case of milk, according to Hills.

Rule.—To find the "overrun" when the weight of butter made from a given amount of milk or cream and the per cent. of fat in the milk or cream are known, *find the number of pounds of fat in the milk or cream by Rule* 1, *and divide the weight of butter by the weight of fat. From the result subtract* 1. Example: What is the "overrun" in case of milk testing 4 per cent. of

fat, when we make 135 pounds of butter from 3,000 pounds of milk? Applying Rule 1, $\frac{3000 \times 4}{100} = 120$, pounds of fat in milk; and $135 \div 120 = 1.125$ ($1\frac{1}{8}$) pounds. $1.125 - 1 = .125$ (12.5 per cent.) or $\frac{1}{8}$. Therefore, the "overrun" is .125 or $\frac{1}{8}$ pound, that is, for each pound of fat in milk there will be made $1\frac{1}{8}$ pounds of butter.

6. FINDING THE YIELD OF BUTTER

Rule.—To find the yield of butter when the per cent. of fat in milk and the weight of milk are known, *find the number of pounds of fat in milk by Rule* 1 *and multiply this result by* 1.17 *or* 1 1-6. Example: How much butter is made from 1,000 pounds of milk containing 4 per cent. of fat? Applying Rule 1, $\frac{1000 \times 4}{100} = 40$, pounds of fat in milk; and $40 \times 1.17 = 46.8$, pounds of butter yield.

In the case of cream apply the foregoing rule, except to multiply by 1.20 instead of 1.17.

The application of this rule finds use in checking creamery work. If the yield, in case of milk, is not in proportion to an "overrun" of 15 to 17 per cent, and in case of cream, 20 per cent., one should ascertain why and then correct such faults as are found to exist in the form of losses of fat or retaining too little water. When the proportion of butter to fat greatly exceeds 1.17 in the case of milk, too much water is retained in the butter, or else the fat-test is improperly made or the results purposely read too low.

EXAMPLES FOR PRACTICE UNDER RULES 5 AND 6

(1) How much butter should be made from 5,000 pounds of milk testing 5 per cent. of fat?

(2) What is the "overrun" when 4,000 pounds of milk, testing 4 per cent. of fat, yield 180 pounds of butter?

(3) A butter-maker has 10,000 pounds of milk, testing 4 per cent. of fat; in skimming this, he produces 8,000 pounds of skim-milk, testing .15 per cent. of fat. After churning, he has 1,600 pounds of buttermilk testing .2 per cent. of fat. The loss of fat in handling the cream and making the butter amounts to 4 pounds. (a) How much fat is left in the butter? (b) How many pounds of butter should be made? (c) What is the "overrun" if he produces 450 pounds of butter?

(4) How much butter should be made from 1,000 pounds of cream testing 35 per cent. of fat?

7. FINDING YIELD OF CHEESE FOR MILK-FAT

Rule.—To find the yield of green cheese for a pound of fat in milk when the weight of the cheese made from a given amount of milk and the per cent. of fat in milk are known, *find the number of pounds of fat in milk by Rule* 1, *and divide the weight of cheese by the weight of fat.* Example: How much cheese is made for one pound of fat in milk, testing 4 per cent. of fat, when we make 63 pounds of cheese from 600 pounds of milk? Applying Rule 1, $\frac{600 \times 4}{100} = 24$ pounds of fat in milk; $63 \div 24 = 2.67$ pounds of cheese

made for one pound of fat in milk. In connection with cheese, this is the same kind of relation as the "overrun" in butter. In cheese-making a pound of fat in milk has added to it enough casein, water, salt, etc., to increase the weight from 1 of fat to 2.7 (more or less) pounds of cheese.

8. FINDING YIELD OF CHEESE FROM FAT IN MILK

Rule.—To find the yield of green cheese from 100 pounds of milk when the per cent. of fat in milk is known, *multiply the per cent. of fat in milk* by 2.7. Example: How much cheese should be made from 100 pounds of milk testing 3.7 per cent. of fat? $3.7 \times 2.7 = 9.99$ pounds.

This rule applies only to normal milk containing 3.6 to 3.8 per cent. of fat. For milk containing fat above 3.8 per cent., the results are usually too high; and for milks containing less than 3.6 per cent. of fat, the results are usually too low.

9. FINDING YIELD OF CHEESE FROM FAT AND CASEIN IN MILK

Rule.—To find the yield of green cheese, containing 37 per cent. of water, from 100 pounds of milk when the per cent. of fat and of casein in milk is known, *add the per cent. of casein and of fat and multiply the sum by* 1.63. Example: How much cheese can be made from 100 pounds of milk containing 4 per cent. of fat and 2.5 per cent. of casein? $(4+2.5) \times 1.63 = 10.60$ pounds of green cheese.

10. FINDING PER CENT. OF CASEIN IN MILK FROM FAT

Rule.—To find the per cent. of casein in milk when the per cent. of fat is known, *subtract* 3 *from the per cent of fat in milk, multiply the result by* .4 *and add this result* to 2.1. Example: How much casein is there in milk containing 4.5 per cent. of fat? (4.5—3) ×.4+ 2.1=2.70 per cent. of casein.

This rule is based upon the writer's work, showing that milk testing 3 per cent. of fat contains an average of about 2.1 per cent. of casein, and that the casein increases, on an average 0.4 per cent. when the per cent. of milk increases 1 per cent. above 3. This is especially true of milks ranging from 3 to 4.5 per cent. of fat when the milk is produced at the same stage of lactation. In the later stages of lactation the ratio of casein to fat is usually greater than is indicated by this rule. (See p. 12).

The above rule is based upon work done in making a careful study in New York State of the milk of each of 50 different herds of cheese-factory cows during one season (May to October). Taking the average of the entire season it was found that 80 per cent. of the results obtained by the method of calculation differed from those given by the chemical method by less than 0.1 per cent.

The above rule can be used in finding the amount of casein and albumin together, the factor 2.9 being added instead of 2.1.

The rule will be found useful by physicians in modifying milk for infant feeding.

11. FINDING YIELD OF CHEESE FROM FAT AND CALCULATED CASEIN

When the per cent. of fat only is known, the amount of casein can be estimated in the manner given in Rule 10 and this figure used for casein in Rule 9; or, better, the two operations of calculating casein and cheese yield can be combined in one simple rule, as follows: *Multiply the percentage of fat by 2.3 and add* 1.4. Example: How much green cheese, containing 37 per cent. of water, can be made from milk containing 4 per cent. of fat? $(4\times2.3)+1.4=10.60$ pounds.

The subject of calculating yield of cheese is fully discussed in Van Slyke and Publow's "Science and Practice of Cheese-Making" (pp. 211-230). As there explained, some of the formulas that have been used extensively have only a limited application when accuracy is considered.

EXAMPLES FOR PRACTICE UNDER RULES 8 TO 11

(1) What is the per cent. of casein in milk containing (a) 3.50, (b) 3.60, (c) 4, (d) 4.4 per cent. of fat?

(2) How much green cheese should be made from 100 pounds of the different milks mentioned in the preceding example? (Apply Rules 9, 10 and 11).

(3) How much green cheese should be made from 18,000 pounds of milk testing 3.75 per cent. of fat?

12. FINDING DIVIDENDS ON FAT BASIS AT CREAMERIES

Rule.—To calculate the amount of each patron's dividend at creameries on the basis of the fat in the milk, *multiply the amount of the milk-fat delivered by each patron by the price of one pound of fat.*

This rule can be made more clear by considering the process in three separate steps, assuming that the creamery is operated on the co-operative plan.

Step 1. By Rule 1 find the amount of milk-fat furnished by each patron during the dividend period.

Step 2. Find the net value of one pound of milk-fat by dividing the total net receipts by the total number of pounds of fat delivered by all the patrons during the dividend period.

Step 3. Multiply the number of pounds of fat delivered by each patron by the net price received for one pound of fat.

Example: Step 1. The data and results are indicated in tabular form as follows:

NAME OF PATRON	*Pounds of Milk delivered during dividend period*		*Per cent. of fat in milk*		*Pounds of fat in milk delivered*
A	350	×	4.0	=	14.00
B	650	×	3.6	=	23.40
C	835	×	5.2	=	43.42
D	965	×	4.4	=	42.46
E	1,200	×	4.2	=	50.40
Total number of pounds of fat delivered by all patrons					173.68

Step 2. From the amount of fat indicated above, the amount of butter made was 195 pounds, which realized 18 cents a pound after deducting all expenses, making a total of $35.10. This sum divided by 173.68, the total pounds of fat delivered, gives 20.2 cents as the net price received for each pound of fat.

Step 3. The data and results are indicated in tabular form, as follows:

NAME OF PATRON	*Pounds of fat delivered*		*Net price received for fat per pound*		*Amount of dividend due each patron*
A . .	14.00	×	20.2 cents	=	$2.83
B . .	23.40	×	" "	=	4.73
C . .	43.42	×	" "	=	8.77
D . .	42.46	×	" "	=	8.58
E . .	50.40	×	" "	=	10.18

When both milk and cream are used in a creamery, the pounds of fat delivered in the form of cream are found by applying Step 1 above and then multiplying the result by 1.02. From this point on, the process of calculating dividends is the same as above described.

13. FINDING DIVIDENDS ON FAT BASIS AT CHEESE-FACTORIES

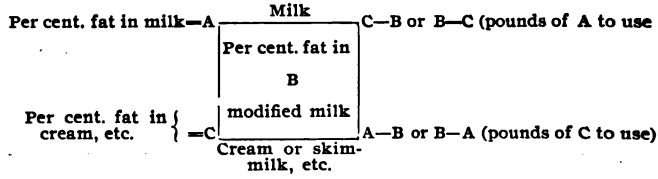
Rule.—To calculate the amount of each patron's dividend at cheese-factories on the basis of the fat in the milk, proceed as under Rule 12.

14. FINDING AMOUNTS OF MILK, ETC., TO USE IN MODIFYING NORMAL MILK

The practice of modifying or standardizing milk for special market purposes is constantly increasing. This consists in increasing or decreasing the per cent. of fat in a normal milk. The per cent. of fat in a normal milk may be increased (1) by adding cream, (2) by adding milk richer in fat, or (3) by skimming part of the normal milk with a separator and then putting the cream thus obtained back into the rest of the normal milk. The per cent. of fat in a normal milk

may be decreased without adding water, (1) by adding skim-milk, (2) by adding milk poorer in fat, or (3) by skimming part of the milk and then putting the skim-milk thus obtained back into the rest of the normal milk.

Prof. R. A. Pearson, of Cornell University, has devised an ingenious method by which one can accurately, quickly and easily find the amounts of milk, cream and skim-milk to be used in modifying or standardizing milk in order to produce a milk containing a desired per cent. of milk-fat. The following diagram and explanation may serve to make clearer the working of the method:


Per cent. fat in milk—A
Milk
C—B or B—C (pounds of A to use
Per cent. fat in
B
modified milk
Per cent. fat in cream, etc.
=C
A—B or B—A (pounds of C to use)
Cream or skim-milk, etc.

Let A represent the per cent. of fat in the milk to be modified.

Let B represent the per cent. of fat desired in the modified milk.

Let C represent the per cent. of fat in the milk, cream or skim-milk which is to be used in increasing or decreasing the per cent. of fat.

The problem is to find in what proportions we shall use the milk, etc., containing A and C, in order to obtain a product containing B.

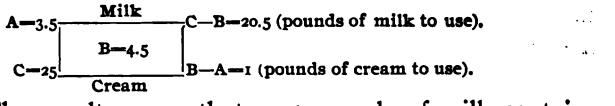
When the per cent. of fat in the normal milk is to be increased, A is less than B, while C is greater than B. In this case, B minus A gives the pounds of

the product containing C to be used, while C minus B gives the pounds of milk (A) to be used or, expressed in another way, the procedure becomes, B—A=pounds of product containing C to be used, and C—B=pounds of milk (A) to use.

When the per cent. of fat in the normal milk is to be decreased in the modified milk, the procedure is thus indicated: A—B=pounds of product containing C to be used and B—C=pounds of milk (A) to be used.

The simplicity of the method becomes readily apparent when practically illustrated.

(1) *When the per cent. of fat in milk is to be increased by addition of cream or richer milk. Rule.—From the per cent. of fat desired in the modified milk subtract the per cent. of fat in the milk to be modified, and the result is the number of pounds of cream or richer milk to be used. From the per cent. of fat in the cream or richer milk subtract the per cent. of fat desired in the modified milk, and the result is the number of pounds to use of the milk to be modified.* Example: What relative amounts of normal milk and cream must be used to produce milk containing 4.5 (B) per cent. of fat, when the normal milk contains 3.5 (A) per cent. of fat and the cream 25 (C) per cent.?



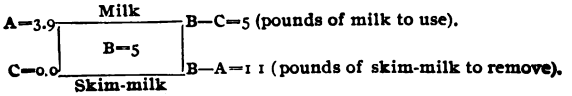
The results mean that 20.5 pounds of milk containing 3.5 per cent. of fat, mixed with 1 pound of cream containing 25 per cent. of fat, will produce a modified

milk containing 4.5 per cent. of fat. If, in place of cream, a milk containing more than 3.5 per cent. of fat were used, the process would be the same.

(a) If it is desired to know how much such cream must be used in standardizing 1,000 pounds of such milk, divide 1,000 by 20.5 (C—B) and multiply by 1 (B—A,) which will give 48.8 pounds of cream to be added and 1048.8 pounds of the modified milk.

(b) If it is desired to know how much such cream and milk to use to make 1,000 pounds of the modified milk, divide 1,000 by 21.5 (C—B) + (B—A), which is 46.5, and multiply this amount by 20.5 (C—B) and by 1 (B—A), which will give 953.5 pounds of 3.5 per cent. milk and 46.5 pounds of 25 per cent. cream.

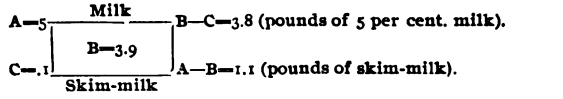
(2) *When the per cent. of fat in milk is to be increased by removing a portion of the milk-serum* (skim-milk). *Rule.—From the per cent. of fat desired in the modified milk subtract the per cent. of fat in the milk to be modified, and the result is the number of pounds of skim-milk to be removed. The per cent. of fat in the modified milk is the number of pounds to use of the milk to be modified.* This is done by separating the cream from a portion of the milk and then adding it to the normal milk. The skim-milk can be assumed to contain practically no fat. Example: How much skim-milk should be removed from milk containing 3.9 per cent. of fat, in order to produce a modified milk containing 5 per cent. of fat?



In this case we add nothing, so that C equals 0 and B—C=5—0=5. The results mean that for 5 pounds of the milk, we should remove 1.1 pounds of skim-milk, thus reducing 5 pounds of milk containing 3.9 per cent. of fat to 3.9 pounds of modified milk containing 5 per cent. of fat.

Applying these results to a specific case, how much skim-milk should be removed from 980 pounds of 3.9 per cent. milk to increase the fat to 5 per cent? Divide 980 by 5 (B—C), which gives 196, and multiply this by 1.1 (B—A) which gives 215.6 pounds of milk-serum or skim-milk to be removed, leaving 764.4 pounds of modified 5 per cent. milk.

(3) *When the per cent. of fat is to be decreased by adding skim-milk. Rule—From the per cent. of fat in the milk to be modified subtract the per cent. of fat desired in the modified milk, and the result is the number of pounds of skim-milk to be used. From the per cent. of fat desired in the modified milk, subtract the per cent. of fat in the skim-milk, and the result is the number of pounds to use of the milk to be modified.* Example: How much skim-milk containing .1 per cent of fat should be added to milk containing 5 per cent. of fat to reduce the fat to 3.9 per cent.?



(a) How much skim-milk should be added to 1,000 pounds of 5 per cent. milk to produce 3.9 per cent. milk? Divide 1,000 by 3.8, giving 263, and multiply the result by 1.1, which gives 289, the number of

pounds of skim-milk. There would be 1,289 pounds of 3.9 per cent. milk.

(b) How much skim-milk is needed to produce 1,000 pounds of modified 3.9 per cent. milk? Divide 1,000 by 4.9, which gives 204.08. This, multiplied by 3.8, gives 775.5 pounds of 5 per cent. milk to use and, multiplied by 1.1, gives 224.5 pounds of skim-milk.

EXAMPLES FOR PRACTICE

(1) What amount of milk containing 4.7 per cent. of fat, and of cream containing 30 per cent. of fat, should be mixed in order to produce 740 pounds of milk containing 6 per cent. of fat?

(2) Mix milk containing 5.2 per cent. of fat with milk containing 3.3 per cent of fat in such amounts as to produce 950 pounds of milk containing 4.1 per cent. of fat.

(3) How many pounds of separator skim-milk must be mixed with 100 pounds of cream containing 20 per cent. of fat in order to produce a modified milk containing 5 per cent. of fat?

(4) How many pounds of skim-milk must be mixed with two pounds of 4.5 per cent. milk in order to produce a mixture containing 3 per cent. of fat?

(5) How much skim-milk must be removed from milk containing 3 per cent. of fat in order to increase the fat to 3.7 per cent.?

15. CORRECTING QUEVENNE LACTOMETER READING FOR TEMPERATURE

Rule.—For each degree F. above 60° *F. add* .1, *and for each degree below* 60° *F. subtract* .1 (See p. 181).

16. CONVERTING QUEVENNE INTO BOARD OF HEALTH LACTOMETER DEGREES

Rule.—Divide the Quevenne reading by .29. (See p. 182.)

17. CONVERTING BOARD OF HEALTH INTO QUEVENNE LACTOMETER DEGREES

Rule.—Multiply the Board of Health reading by .29. (See p. 182.)

18. CORRECTING BOARD OF HEALTH LACTOMETER READING FOR TEMPERATURE

Rule.—For each degree F. of temperature above 60° F. add .3, and for each degree below 60° F. subtract .3. (See p. 184.)

19. CHANGING VOLUME INTO WEIGHT

Rule.—To convert a known volume of a liquid into pounds when the specific gravity is known, *multiply the specific gravity of the liquid by the weight of an equal volume of water.* Example: One gallon of water weighs 8.33 pounds; what is the weight of a gallon of milk whose specific gravity is 1.032? Multiplying 8.33 by 1,032, we have as the answer 8.6 pounds.

20. CHANGING POUNDS OF MILK INTO QUARTS

Rule.—Divide the number of pounds of milk by 2.15. Example: How many quarts of milk in 100 pounds? $100 \div 2.15 = 46.5$ quarts.

21. CHANGING QUARTS OF MILK INTO POUNDS

Rule.—Multiply the number of quarts by 2.15. Example: How many pounds in 40 quarts of milk? 40 ×2.15=86 pounds.

22. CHANGING DEGREES FAHRENHEIT INTO DEGREES CENTIGRADE

Rule.—From the degrees F. subtract 32 *and multiply the result by* 5-9. Example: 162° F.=(162—32) ×5-9=72° C.

23. CHANGING DEGREES CENTIGRADE INTO DEGREES FAHRENHEIT

Rule.—Multiply the degrees C. by 9-5 *and add* 32. Example: 72° C.=(72×9-5)+32=162° F.

24. FINDING THE TRUE AVERAGE

Rule.—To find the true average per cent. of fat in different lots of milk or milk products, *find the weight of fat in each separate lot by Rule* 1, *add these amounts and divide the sum by the total weight of milk or milk products.* Example: What is the average per cent. of fat in the following lots of milk?

Pounds of milk		*Per cent. of fat*	*Pounds of fat*
400	containing	4.3	17.2
300	"	3.4	10.2
800	"	5.2	41.6
100	"	3.1	3.1
1,600			72.1

Applying Rule 1, we find the weight of fat in each lot of milk, the results being indicated in the third column above. The total amount of fat in all of the milks is 72.1 pounds, which, divided by 1,600 (the total weight of milk), gives 4.5 as the real average per cent. of fat in all the milk.

It is wrong to regard as the average per cent. the result obtained by adding the per cents. directly and then dividing this sum by the number of lots represented, unless the amounts of milk or milk products are equal. Thus, in the foregoing example, the result of such a wrong method would make the average 4 per cent., when it is really 4.5.

The same principle explains why we do not get a true average composite sample, when we take the same amount of milk from different lots that vary considerably in weight and per cent. of fat.

EXAMPLES FOR PRACTICE

(1) Find the average per cent. of fat in the following lots of milk: 1,200 pounds, 3 per cent. of fat; 2,000 pounds, 5 per cent. of fat; 6,000 pounds, 4 per cent. of fat; and 1,800 pounds, 3.5 per cent. of fat.

(2) Find the average per cent. of fat in 1,000 pounds of cream, 40 per cent. of fat; 1,600 pounds, 30 per cent. of fat; and 400 pounds, 20 per cent. of fat.

25. FINDING AMOUNT OF CREAM

Rule.—To find the amount of cream produced for 100 pounds of milk when the per cent. of fat in milk and in cream is known, *divide the per cent. of fat in*

milk by the per cent. of fat in cream and multiply the result by 100. Example: How many pounds of cream containing 25 per cent. of fat are produced from 100 pounds of milk containing 5 per cent. of fat? 5÷25=.2. .2×100=20, number of pounds of cream with 25 per cent. of fat.

26. FINDING AMOUNT OF SKIM-MILK

Rule.—To find the amount of skim-milk for 100 pounds of milk when the per cent. of fat in milk and in cream is known, *find the amount of cream by Rule* 25 and then subtract this from 100. Example: How much skim-milk is produced from 100 pounds of milk containing 4 per cent. of fat when the cream contains 25 per cent of fat? 4÷25=.16; .16×100=16; 100—16=84, number of pounds of skim-milk.

27. FINDING AMOUNT OF BUTTERMILK

Rule.—To find the amount of buttermilk for 100 pounds of milk when the per cent. of fat in milk and in cream is known, *multiply the amount of fat in* 100 *pounds of milk by* 1.17 *and subtract the result from the amount of cream.* Example: How many pounds of buttermilk are produced for 100 pounds of milk containing 4 per cent. of fat, when the cream used contains 25 per cent. of fat? 4×1.17=4.68 (pounds of butter made); 4÷25×100=16 (pounds of 25 per cent. cream); 16—4.68=11.32 (pounds of buttermilk).

28. FINDING SPECIFIC GRAVITY OF MILK-SOLIDS

Rule.—To find the specific gravity of milk-solids, when the specific gravity of the milk and per cent. of milk-solids are known, *multiply the specific gravity of the milk by* 100, *from the result subtract* 100 *and divide this result by the specific gravity of the milk. Subtract the last result from the per cent. of milk-solids and then divide this result by the per cent. of milk-solids.* (See p. 187).

29. FINDING AMOUNT OF ADDED WATER IN MILK

See page 201.

30. TABLE SHOWING APPROXIMATE EQUIVALENTS OF METRIC SYSTEM

1 fluid ounce	=	29.60	cubic centimeters (cc.)
1 quart	=	0.95	liter (1)
1 gallon	=	3.8	liters.
1 grain	=	65.	miligrams (mg.)
1 ounce (av.)	=	28.35	grams (gm.)
1 pound	=	.45	kilogram (kg.).

APPENDIX

STANDARDS FOR GLASSWARE USED IN BABCOCK TEST

So great variations were found in the forms and accuracy of the glassware used in the Babcock test that it became necessary for official bodies to make investigations and adopt certain recognized standards. The Dairy Instructors' Association, in 1911, adopted detailed specifications in regard to the construction and graduation, etc., of such glassware, while the Association of Official Agricultural Chemists, in 1908, adopted standards of accuracy and rules for testing, as given below:

SPECIFICATIONS FOR CONSTRUCTION AND GRADUATION OF STANDARD BABCOCK GLASSWARE

The following are standard Babcock test-bottles for milk and cream:

(1) Milk-test bottles, 8 per cent., 18-gram, 6-inch.
(2) Cream-test bottles, 50 per cent., 9-gram, 6-inch.
(3) Cream-test bottles, 50 per cent., 9-gram, 9-inch.

Standard milk-test bottles: 8 per cent., 18-gram, 6-inch.—(1) *Graduation*—The total per cent. graduation shall be 8. The graduated portion of the neck shall have a length of not less than 63.5 mm. (2½ inches). The graduation shall represent whole per cent., five-tenths per cent. and tenths per cent. The tenths per cent. graduations shall be no less than 3 mm. in length;

the five-tenths per cent. graduations shall be 1 mm. longer than the tenths per cent. graduations, projecting 1 mm. to the left; the whole per cent. graduations shall extend one-half way around the neck to the right and projecting 2 mm. to the left of the tenths per cent. graduations. Each per cent. graduation shall be numbered, the number being placed on the left of the scale. The error at any point of the scale shall not exceed one-tenth per cent.

(2) *Neck*—The neck shall be cylindrical for at least 9 mm. below the lowest and above the highest graduation mark. The top of the neck shall be flared to a diameter of not less than 10 mm.

(3) *Bulb*—The capacity of the bulb up to the junction of the neck shall not be less than 45 cc. The shape of the bulb may be either cylindrical or conical, with the smallest diameter at the bottom. If cylindrical, the outside diameter shall be between 34 and 36 mm.; if conical, the outside diameter of the base shall be between 31 and 33 mm. and the maximum diameter between 35 and 37 mm.

(4) *The charge* of the bottle shall be 18 grams.

(5) *The total height* of the bottle shall be between 150 and 165 mm. (5⅞ and 6½ inches).

(6) Each bottle shall bear a permanent identification number.

Standard cream-test bottles: 50 per cent., 9-gram, so-called 6-inch, and 9-inch.—(1) *Graduation*—The total per cent. graduation shall be 50. The graduated portion of the neck shall have a length of not less than 63.5 mm. (2½ inches). The graduation shall represent 5 per cent., 1 per cent., and five-tenths per cent. The five-tenths per cent. graduations shall be at least 3 mm. in length; the 1 per cent. graduations shall be 2 mm. longer than the five-tenths per cent. graduations, projecting 2 mm. to the left; the 5 per cent. graduations shall extend halfway around the neck to the right and project 4 mm. to the left of the five-tenths per cent.

graduations. Each 5 per cent. graduation shall be numbered, the number being placed on the left of the scale. The error at any point of the scale shall not exceed five-tenths per cent.

(2) *Neck*—(Same as standard milk test-bottle). The neck shall be cylindrical for at least 9 mm. below the lowest and above the highest graduation mark. The top of the neck shall be flared to a diameter of not less than 10 mm.

(3) *Bulb*—(Same as standard milk test-bottle). The capacity of the bulb up to the junction of the neck shall not be less than 45 cc. The shape of the bulb may be either cylindrical or conical, with the smallest diameter at the bottom. If cylindrical, the outside diameter shall be between 34 and 36 mm.; if conical, the outside diameter of the base shall be between 31 and 33 mm. and the maximum diameter between 35 and 37 mm.

(4) *The charge* of the bottle shall be 9 grams.

(5) *The total height* of the 6-inch bottle shall be between 150 and 165 mm. (5⅞ and 6½ inches), (same as standard milk-test bottles); of 9-inch bottles, between 210 and 225 mm. (8¼ and 8⅞ inches).

(6) All bottles shall bear on top of the neck, above the graduations, in plainly legible characters, a mark defining the weight of the charge to be used (9 gram).

Each bottle shall bear a permanent identification number.

Standard Pipette.—Total length of pipette not more than 330 mm. (13¼ in.).

Outside diameter of suction tube, 6 to 8 mm.

Length of suction tube, 130 mm.

Outside diameter of delivery tube, 4.5 to 5.5 mm.

Length of delivery tube, 100 to 120 mm.

Distance graduation mark above bulb, 50 to 60 mm.

Nozzle, straight.

Delivery, 17.6 cc. of water at 20 degrees C. in 5 to 8 seconds.

STANDARD OF ACCURACY FOR BABCOCK GLASSWARE AND RULES FOR TESTING

SECTION 1.—*The unit of graduation* for all Babcock glassware shall be the true cubic centimeter (.998877 gram of water at 4 degrees C.).

(*a*) With bottles, *the capacity of each per cent.* on the scale shall be two-tenths (0.20) cubic centimeter.

(*b*) *With pipettes and acid measures,* the delivery shall be the intent of the graduation, and the graduation shall be read with the bottom of the meniscus in line with the mark.

SECTION 2—*The official method for testing bottles* shall be calibration with mercury (13.5471 grams of clean, dry mercury at 20 degrees C., carefully weighed on analytical balances, to be equal to 5 per cent. on the Babcock scale), the bottles being previously filled to zero with mercury.

SECTION 3—*Optional methods*—The mercury and cork, alcohol and burette, and alcohol and brass-plunger methods may be employed for the rapid testing of Babcock bottles, but the accuracy of all questionable bottles shall be determined by the official method.

SECTION 4—*The official method for testing pipettes* and acid-measures shall be calibration by measuring in a burette the quantity of water (at 20 degrees C.) delivered.

SECTION 5—*The limits of error*—(*a*) For Babcock bottles shall be the smallest graduation on the scale, but in no case shall it exceed five-tenths (0.50) per cent., or for skim-milk bottles one-hundredth (0.01) per cent.

(*b*) For full-quantity pipettes, it shall not exceed one-tenth (0.10) cubic centimeter, and for fractional pipettes, five-hundredths (0.05) cubic centimeter.

(*c*) For acid-measures it shall not exceed two-tenths (0.20) cubic centimeter.

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